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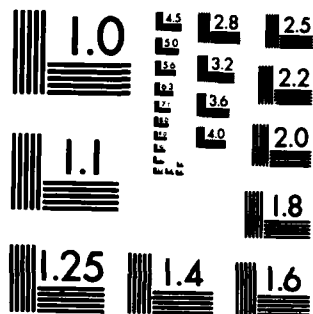
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EUROPEAN SCIENTIFIC NOTES OFFICE OF NAVAL RESEARCH LONDON

Edited by Vivian T. Stannett
Larry E. Shaffer

Vol 37, No. 2 28 February 1983

BEHAVIORAL SCIENCES

Human Factors in Robots and Programmable Control Devices N.A. Bond, Jr. 53

"Robotic" machinery continues to demonstrate its efficiency, but much human factors planning and integration is required for a successful operation.

CHEMISTRY

The 9th International Mass Spectrometry
Conference J. Campana, J.R. Wyatt, F.E. Saalfeld 58

The conference focused on secondary ion mass spectrometry, fast atom bombardment mass spectrometry, and mass spectrometry combined with analytical techniques.

Polymers and Radiation at the Royal Military College
of Science V.T. Stannett 59

Polymer research, mainly based on the use of high energy radiation, is under way at the RMCS. In particular, pulsed nuclear magnetic resonance is being used to study the effects of radiation on polymers.

COMPUTER SCIENCES

Computer Science at Oxford Univ. J.F. Blackburn 61

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Plessey is embarking on a 5-year program of building and of research and development to maintain its lead as the largest UK producer of III-V semiconductor devices. A major interest is in information transmission development.

Scientists Meet To Improve Semiconductor Surfaces
and Interfaces M.N. Yoder 66

The future of very large scale integrated circuits critically depends on profit margins, which in turn depend on an understanding and control of the semiconductor surface. Scientists recently convened in Trieste to share new advances in the physics and chemistry of the semiconductor surface.

MATERIAL SCIENCES

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OPERATIONS RESEARCH

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Laser Projection Video D. Mosher 75

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F.A. Richards
Chief Scientist



L.B. Sykes
Captain, USN
Commanding Officer

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BEHAVIORAL SCIENCES

HUMAN FACTORS IN ROBOTS AND PROGRAMMABLE CONTROL DEVICES

A recent international review is entitled "The Robots are Coming--Slowly," and that title pretty well expresses the prevailing state of robot usage in Europe. Some famous and spectacular success stories are described over and over again, but even the most optimistic analyst would have to say that robots' "limitless potential" is largely unrealized. The United Kingdom, for example, still has only one major manufacturer of robotic equipment, and only a few hundred installed robots.

There are reasonable explanations for the lack of growth. One is that the technical problems often have been more difficult than they seemed at first. As late as last year, there still was not a single machine that could pick a piece, such as a stamped compressor cover, from a tub full of parts, inspect it carefully for defects, place it on a compressor, and screw it into place with controlled torque on several nuts. The bits-and-pieces technology to do this was available in laboratories around the world. For example, special little sensors--still in the experimental stage--can put the screws on without stripping the threads. The vision system to recognize key features of the plates as they are moved about can be effected in a laboratory, but it is very expensive and requires much local debugging. And the computer programs to tie together the components have not been developed for practical use.

Robot Survey

Other obstacles to a "Robot Age" include the equipment payback period and other economic uncertainties, the scale of government support for robotic concepts and demonstrations, and the resistance of managers and human workers to machines which are perceived as replacements for people. Such factors have been under investigation by a team from the Universities of Birmingham and Nottingham. In a long-term project, Prof. E.N. Corlett (from Nottingham's Production Engineering Department), and Drs. R.J. Bradbury and K.M. Hogan (from Birmingham's Psychology Department) visited UK plants and talked to executives and workers about successes and failures in working with automatic machinery. Most of the sites visited had more than 15,000 employees, but some small firms were included.

As it happened, the survey was done as Britain was undergoing a severe industrial recession; hundreds of plants closed during 1980-81. (Well over 3 million people were unemployed as of January 1983.) In a few cities the unemployment rate was above 20%, the highest in nearly 50 years; for some months in 1981 the Strathclyde area west of Glasgow was losing 137 jobs a day. In such a difficult period, a study of the problems and achievements of technical change has a special relevance, and the persisting financial crisis sharpens the question of whether robotics and related technologies really can offer a way out of economic difficulties.

Economics

One of the first facts that any robot survey shows is the difference in utilization within various countries. Of course, there are difficulties in deciding just what a robot is (most definitions include programmability and multifunction manipulation). Though estimates vary, Japan seems to be the leading user, with at least 7,000 installed in 1980. The next three countries are the US, with some 4,000; West Germany (1,250); and Sweden (about 1,000). The UK, though still a major trading nation and dependent on exports for nearly 30% of its gross domestic product, has a low utilization rate, well behind France and Italy. According to Corlett, Bradbury, and Hogan, the most likely explanations for the UK's inactivity are economic. Britain now has a high cost of capital, primarily because many investors prefer to buy real estate or government-type "gilt" bonds rather than to put money into industry. The high cost of money then reduces the required payback time for any new industrial investment, so that only innovations promising really short amortization will be funded. The uncertainties and lack of convincing experience with robots may also argue against the possibility that the equipment will quickly pay for itself.

Another economic factor is the cost of labor. British hourly labor costs are about half of those in places such as West Germany, Scandinavia, and the Netherlands, and British social welfare payments are held to a subsistence level. But when low labor costs are accompanied by low productivity, the economic analyses show that there is little "cost-push" incentive for investment. The high job security and social welfare benefits in a country such as Sweden, for example, force up the value of productive labor, and the high pay

supposedly provides the "push" for investment in new plant and for an ever-improving standard of living.

A company considering a new and expensive robotic installation may not think much in terms of general economics, or care much about national cost-push impetus to investment. It might, though, look carefully at the "learning curve" phenomenon in production. When production runs are lengthened, the early bugs and little problems are ironed out and unit costs can drop sharply, perhaps on the order of 25% for each doubling of the original production run. Such increased efficiency can be decisive in an international competitive market. But the analyses by Corlett et al. show that there is another important feature: to get through the early part of the learning curve, when most of the planning and production bugs are discovered and eliminated, a large and stable home market is necessary. Indeed, some analysts believe that the success of many Japanese products is partly due to a captive but competitive home exposure phase. During that phase, not only is the technical learning curve improving in the factories, but the public's reaction is under intensive trial and review. (The process, incidentally, could account for minor but decisive design features. For example, a popular Japanese cassette recorder, when stopped, automatically "stepped back" a second or two before the stopping spot, allowing easy reference for the person originating or transcribing the tape. Western cassette recorders did not have this "obvious" feature until a year or so after the Japanese.) The home trial market, then, probably will be more effective in countries that have high personal savings, high wages, and high productivity. In fact, tabulations show that robots are used more under just such conditions.

Technical Efficiency

Thus it seems that economic considerations can go far toward predicting whether the capitalization and trial of robotic equipment will take place. Once the investment is made, technical efficiency may become the most important variable affecting decisions. A good illustration is the Longbridge plant near Birmingham, which is now assembling the Mini-Metro, one of British Leyland's new cars. The total Mini-Metro program required an investment of £275 million, or more than \$500 million. Automatic warehousing and assembly operations were the key segments of the program.

In one major body store, all major body stampings are received in pallets

from the suppliers; the pallets pass through a recognition point, where an operator passes a pen over the pallet label. The store computer immediately decides the store location for that load, and calculates present and projected stock levels and the best sequence of recovering the pallet for later manufacturing. Automatic stacker cranes can move a pallet into its computed location within a minute or two. The vast body store building is from 8 to 10 stories high and can accommodate more than 3,000 pallets. Some deliveries from the store are still made by manually operated fork lift trucks. But in a few years, it is expected that receipt, storage, and recovery will be almost completely automatic. Figure 1 shows a section of the body parts store. Employees are responsible primarily for monitoring the automatic systems.

Assembly automation was planned so that 6,500 to 7,500 cars a week could be produced (in the present recession, actual production is often lower). Eighty-five major steel pressings must be put together for each car. The work proceeds by automatic welding of subassemblies, which finally grow into a complete auto body. Time cycles at each stage vary according to the complexity involved; a front fender cycle might be 25 seconds, whereas an underfloor frame assembly produces a finished unit with several parts every 50 seconds. In many of the operations the "growing" car assembly is transferred and turned over automatically by the various devices. A seven-unit queuing pattern for supply pallets is the general component backup policy.

Perhaps the most spectacular assembly operations take place in the "Kuka towers" at the Longbridge plant. The Kuka machines produce a major body subassembly every 50 seconds; to do this they have many multiwelder stations and loaders. Most of the major operations can be inspected with a special video display unit, and there are precise automatic inspections throughout a major subassembly run.

"Body framing" is the part of the assembly process where over a dozen Unimate robots do the finish welding. Starting with a skeleton that is just stable enough to permit handling, the framing cycle ends with a body that is complete except for doors, hood, and front fenders. An automatic inspection scheme accomplishes and displays the results of 24 key measurements on each body; rejects are handled manually further downstream. Human decisions regarding the fate of each assembly are aided by the video and hard-copy dis-

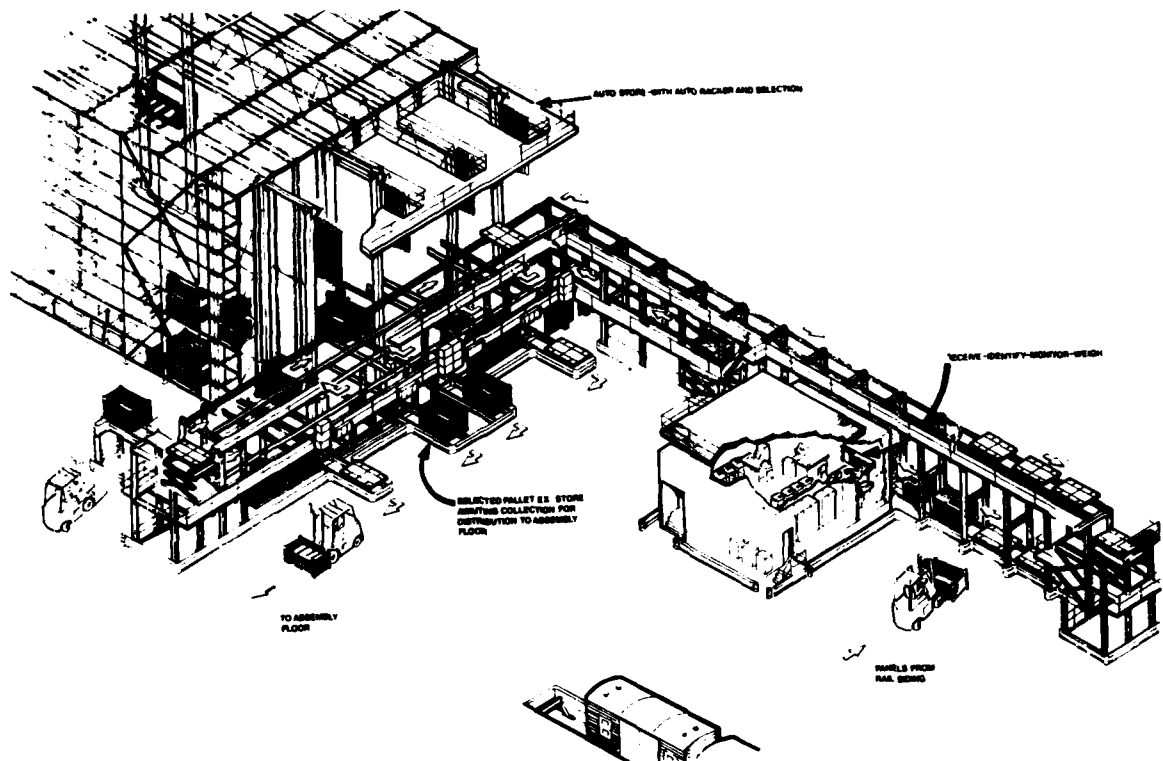


Figure 1. Automatic warehousing for Mini-Metro body stampings.

plays of readings. Though much manual work is still done at various places, few people can be seen in the Kuka and final body areas. In body painting and cathodic electrocoat, hardly any workers are near the cars. Figure 2 shows the major body assembly operation.

Production manpower efficiency is always hard to measure, but on one study this new assembly scheme British Leyland recorded an overall reduction of 7.5 man-hours per car down to 4.4 man-hours. Also, the "first-time accuracy" of the output assemblies was appreciably higher, and there may be important hidden savings from all the automatic conveyors, elevators, and cranes. Though actual worker data have not been released, there are suggestions that the people who watch the assembly operation have higher job satisfaction than they did on an old-fashioned line.

A robotics expert might observe that few of the machines at Longbridge represent "true" robots, and that the plant simply represents an incremental example of conventional automatic machinery. In several respects, how-

ever, such plants really do use complex robotic devices. One of the final Unimate welders, for example, has a more complex and flexible program in it than the others, and it can "clean up" some of the welds which were missed upstream. Another phase of the assembly requires careful monitoring by both man and machine: two complex curved stampings are fitted and welded together according to a very complex profile. The whole system is managed through more than a dozen computers. There are over 50 video display units, and even a private microwave communications link between different factories. In fact, it has been asserted that Longbridge can match the productivity of any automobile plant in Europe.

The technology and investment at Longbridge have several payoffs: dimensional tolerances and overall quality are decisively better, there is an extremely low rejection rate, trend data in the hard-copy production print-outs can predict trouble in advance, there are no complaints or claims from workers or health officials about the

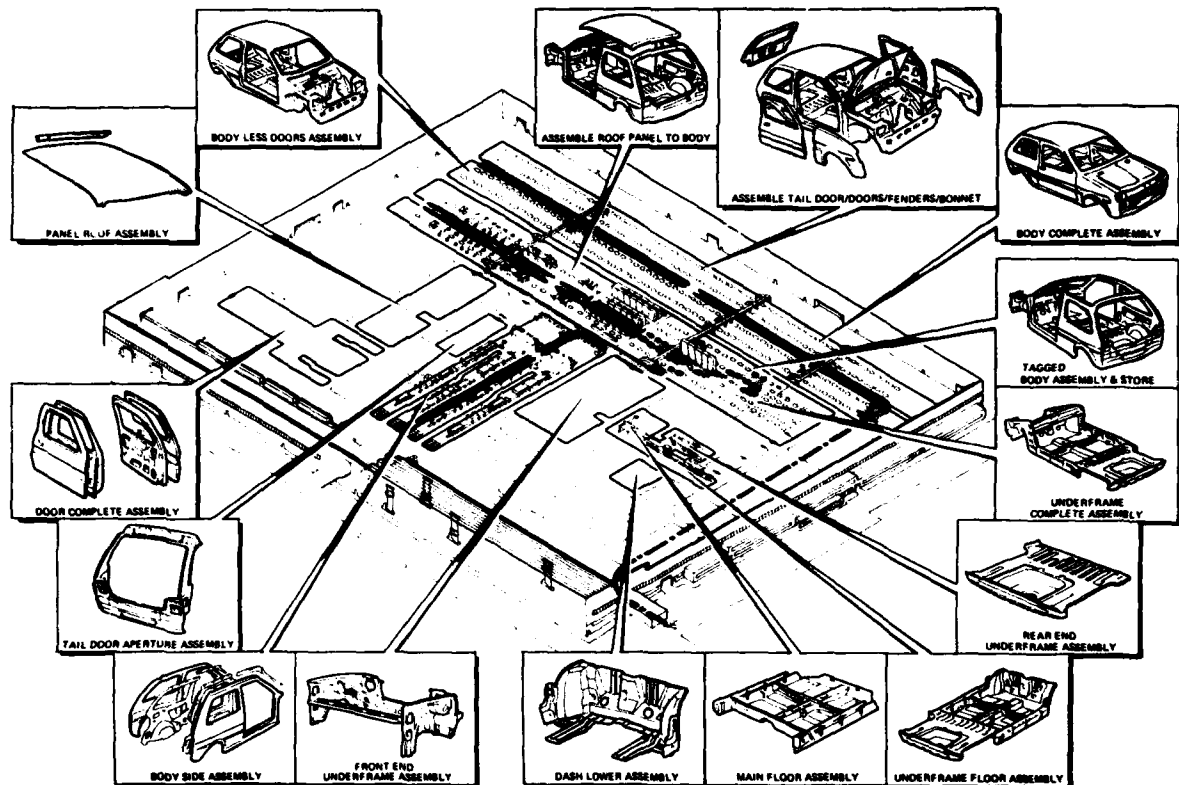


Figure 2. Body assembly sequence.

hazards of anodic electrocoating chambers or paint spray booths, and the degree of control over the processes makes it relatively easy to find and repair faults. The work is often quite skilled, even though fewer workers are needed. The experience ties in with the general rule that each assembly or fastening robot will replace five jobs. (One General Motors announcement predicted "robotic-included reduction" in employment of 60,000 workers over the next 9 years.)

The Future of Robotics

But it is true that the impressive operation at British Leyland is technically somewhat conservative. It cannot easily accommodate disparate streams of input parts and produce different output assemblies, and much of the decision structure is logically not far above the punched-card approach. Though there are computer transfers of data on starting and measuring operations, the more advanced flexibilities of software

control often are not fully utilized; indeed, the installation was set up to be efficient but not particularly flexible. The head of one robot manufacturing concern recently estimated that, with true robotics, 60% of the savings comes from the efficiency of changing over from one product to another. In some cases, the change can be made simply by entering different numbers into a keyboard. Except for certain dimensional changes, however, the big automotive machines almost always require extensive manual change-over.

Perhaps there is an analogy here with the early use of digital computers in the data-intensive industries of insurance, banking, and government services. Such industries always produce many checks, bills, lists, and reports; until about 1955, the processing of the material was done through a semi-automated procedure involving punched cards, mark-sensed forms, slow but reliable electromechanical account-

ing machinery, and the physical filing of pieces of paper. When fast and reliable computers of the IBM 650 generation were introduced, management was glad to have the greater speed and the more convenient electronic data storage on tapes. But the essential operations were not quickly changed--they were just done more quickly and made less cumbersome.

After some years, management gradually realized that entirely new types of analyses were possible, so the computer use became more sophisticated. Eventually, very complex data summaries, simulation models, and other advanced computations came to be expected, and the computer software routines in a big modern company are now far more than an imitation of old payroll and billing routines. The point is that management gradually learned to accept and seek capabilities that did not exist before, and at the same time the computer hardware people were able to offer ever-increasing achievements in storage, speed, and system cost.

There is reason to think that, for robotics really to take hold, parallel growth in management understanding and hardware capability will have to take place. One factor encouraging such growth is that the labor-cost to robot-cost ratio in some countries can be expected to keep rising. According to one analysis, an American automotive worker cost about \$17 an hour in 1980, while a six-axis semi-controlled drilling robot costs only \$4 an hour, amortized over 8 years.

A good illustration comes from General Dynamics, where a drilling robot reportedly saved \$100,000 per work station per year. The machine used a template fitted with hardened drill bushings and inserted the drill with a flexible drill holder (arm placements are often accurate only to about a millimeter). Sensors could tell when the drilled hole was completed; if the drilling took too long, the machine assumed a new drill was needed, discarded the old one, and got a new one from an automated bin. If labor costs keep rising about 8% a year and robot costs keep dropping, then routine drilling, fed from a continuous parts line, may no longer be done by humans even in relatively short production runs.

The Corlett study indicated that more than half the UK robot installations visited were considered unsatisfactory, for various reasons. In one factory, a robot was set to send partially processed pieces of hot metal to teams of workers who further processed

the pieces. The machine sent the pieces according to schedule, but that was just the trouble: the workers wanted a supply system more responsive to their immediate needs. In other unsatisfactory histories, robots were tied into relatively inefficient production systems, and any improvements were masked by the overall inefficiency and lack of integration.

The resistance of workers to robots and automatic equipment is often mentioned, and many unions strongly state that saving jobs is more important than efficient production. This attitude is seen in perhaps its most extreme form in the printing industry, where some highly paid people do useless layout work, which is destroyed upon completion, and which is never used except as a source of printer's wages. Despite such cases, the Corlett team believes that the resistance to robots often may be exaggerated, and this opinion is supported by other investigators. For one thing, workers in industries such as steel, electronics, and automobiles know that the competition among companies and countries is intense, and that productivity is, if not the "name of the game," at least an important part. In addition, industrial psychologists now know more about the factors that influence resistance to change, and presumably can do a better job of preparing workers for new methods. Therefore, we can be fairly optimistic that workers will not resist change so much.

Studies like that being done by the Corlett team occupy an interesting ground, somewhere between the general management literature and detailed engineering studies of specific robotic installations. The field is so complex that the conclusions of the work are necessarily rather qualified and hesitant. Yet the results help suggest what is to come.

Over the next decade or two, there will be more and more cases in which robotics can be economically effective, usually as parts of a larger production process that requires flexibility for minor changes in product parameters and handling requirements. As the cases increase in number, the technology will improve, hardware costs will go down, management will learn more about what "true robotics" can do, and problems such as the lack of systems that recognize visual patterns will be solved for a few standard applications. Such conditions will lead, in uneven but inevitable steps, to truly flexible production systems. At various points along the route, we can hope, what is

known about the psychology of introducing change can aid simultaneously the development of automated production and the worker's quality of life.

N.A. Bond, Jr.

CHEMISTRY

THE 9TH INTERNATIONAL MASS SPECTROMETRY CONFERENCE

The 9th Triennial International Mass Spectrometry Conference was held in Vienna, Austria, from 30 August through 3 September 1982.

The conference included seven plenary lectures, 20 keynote speakers, one panel discussion, 79 contributed papers, and almost 400 poster papers. All plenary lectures and many keynote lectures were presented as overviews of a special topic. This was very educational because of the rapidly growing diversity in the field of mass spectrometry. C. Brunnee (Finnigan MAT, GmbH, FRG) delivered the opening plenary lecture entitled "Instrumentation in Mass Spectrometry"; it set a high standard for the meeting. Brunnee discussed the history and importance of mass spectrometry. Other notable plenary lectures were by D. Hunt (Univ. of Virginia) on "New Ionization Techniques in Mass Spectrometry" and by B. Blanchard, Commissariat a l'Energie Atomique-Centre d'Etudes Nucléaire, Grenoble (CEA-CENG, France) on the "Analysis of Solids and Surfaces by Mass Spectrometry."

As in the past, mass spectrometry in biomedical applications was featured throughout the meeting, again showing the ever-increasing use of mass spectrometry in the medical sciences.

Of particular interest to the authors was the emergence of stimulating discussions on secondary ion mass spectrometry (SIMS). As noted during the eighth conference (F.E. Saalfeld, J.J. Decorpo, and J.R. Watt, ESN 33-12:501 [1979]), the area holds promise for future development. The promise is being fulfilled, and there were several papers dealing with organic SIMS.

An entire oral session and over 40 poster papers were devoted to the new technique of fast atom bombardment mass spectrometry (FAB). The technique, already in wide use, was discovered after the 1979 conference. FAB refers to an ionization technique in which an

involatile or thermally labile organic or biological sample is dissolved in an organic liquid matrix, most commonly glycerol, which is bombarded with a 5- to 10-keV atom or ion beam. The bombardment produces intense ion emission, including molecular-like ions of the sample. Molecular ions from samples having molecular weights over 4,000 have been observed. The original work was done using atom bombardment, hence the name FAB. Several times during the session, there was lively discussion about whether the name "liquid SIMS" would be more appropriate because the techniques are fundamentally identical. However, the name "FAB" will dominate.

Although the emission of molecular ions from solid surfaces by ion bombardment has been studied for more than a decade, the SIMS technique was limited because of rapid destruction of the sample by bombardment-induced damage. The key to FAB is the use of a liquid matrix, which can continually renew the surface with sample molecules by rapid diffusion of the solute to the surface under particle bombardment. Typically a sample in glycerol produces intense ion emission for 15 to 20 minutes. If the same particle bombardment flux were used on a solid organic sample, the molecular emission would last less than a second.

It is now generally believed that the strongest ion emission is produced when the sample goes into the matrix as an ion. Hence, the surface of the solvent is coated with "preformed" sample ions. Little is known, however, about the exact mechanism by which bombardment of the surface liberates such ions to the gas phase.

One area of speculation was the mass limit for FAB. Workers studying the production of high-mass ions from surfaces penetrated by megaelectronvolt particles observed insulin (MW 6000) and insulin dimers (MW 12,000). Work at the Naval Research Laboratory by the authors has produced cluster ions of MW 25,000 from cesium iodide using an FAB source. FAB has already demonstrated extraordinary potential enabling mass spectrometry to be used to study an enormous number of important compounds previously inaccessible to it.

As was reported in ESN 3 years ago, the 1979 Triennial Conference focused attention on the usefulness of organic SIMS and the similarities between SIMS high temperature mass spectrometry and other surface analysis techniques such as Auger spectroscopy. ONR London has sponsored two conferences on ion formation from organic solids. One was reported by R.J. Colton (ESN 35-1:1-5

[1981]); the second will be discussed in an ONRL conference report.

Several sessions were devoted to mass spectrometry (MS) combined with other analytical techniques: gas chromatography (GC/MS), liquid chromatography (LC/MS), supercritical fluid chromatography, and even mass spectrometry-mass spectrometry (MS/MS). The latter combination has proven to be particularly powerful, offering high selectivity, sensitivity, and real-time analysis capability.

R. Yost of the Univ. of Florida showed how triple quadrupole mass spectrometry could be used to measure subpicogram quantities of materials that previously could not be analyzed by either GC/MS or LC/MS. G. Cooks of Purdue Univ. discussed the merits of combining different types of mass spectrometers. Most MS/MS work has been done using quadrupoles or magnetic instruments. A particularly attractive combination consists of a hybrid MS/MS system using a magnetic mass spectrometer with its higher mass and resolution properties for the primary analyzer, and a quadrupole analyzer with its high sensitivity and strong focusing capabilities for the second analyzer. Commercial versions of the hybrid mass spectrometer-mass spectrometer were announced at the meeting.

The conference was organized by J.F.K. Huber and E.R. Schmid of the Univ. of Vienna. It was sponsored by the Austrian Federal Minister of Science and Research, the Vienna Tourist Board, the International Union of Pure and Applied Chemistry, Balzers Hochvakuum GmbH, Finnigan MAT GmbH, Kratos GmbH, and Leybold-Heraeus GmbH. Delegates from more than 30 nations attended; the Federal Republic of Germany and Great Britain had the largest representation.

Complete proceedings will be published as advances in Mass Spectrometry, Vol 9; an early publication of the plenary and keynote presentations is scheduled for 1983 in the International Journal of Ion Mass Spectrometry and Ion Physics.

J.E. Campana, J.R. Wyatt, F.E. Saalfeld
ONR, Arlington, VA

POLYMERS AND RADIATION AT THE ROYAL MILITARY COLLEGE OF SCIENCE

The UK's Royal Military College of Science (RMCS) is a degree granting,

fully residential college. Its main mission is to provide technical training to Army officers, who can take formal degrees or advanced courses. About a quarter of the approximately 500 students, however, are civilians. Accounts of nonpolymer activities and general descriptions of the college have been published in three previous ESN articles: D.K. Cheng, 30-3:116 (1976); J. Perkins, 33-8:314 (1979); and T.C. Cheston, 34-3:117 (1980).

Polymer science, particularly concerned with high energy radiation effects and applications, has been a subject of active research since 1957, when A. Charlesby joined the college as head of the Physics Department. Although officially retired, he is still productive. Several other faculty members continue to be active in radiation and other aspects of polymer research. In addition to the usual polymer physics and chemistry equipment, RMCS has excellent radiation sources, including one large ($\sim 11,000$ curie) cobalt 60 facility leading to a maximum dose rate of 3.5 Mrads/hr, several smaller cobalt sources, and 400-kV and 2MeV Van der Graaf electron accelerators.

Charlesby was one of the original discoverers of the crosslinking of polymers by high energy radiation and the related memory effect with semicrystalline polymers. At the RMCS he has begun pioneering work in almost every aspect of the physics and technology of radiation effects with high polymers: radiation induced polymerization, grafting, crosslinking, degradation, and some application-oriented research. (See ESN 37-1:11 [1983] for a full review of the present status of the general field.) Charlesby's recent work has pioneered the use of pulsed nuclear magnetic resonance (NMR) to yield valuable information on the crosslinking and entanglement densities of long chain polymers. He has used a Spin-Lock CPS-2, pulsed 40-MHz spectrometer for most of his work. The average molecular weight between crosslinks, M_c , the network fraction (degree of cure), and the number of entangled units can be obtained. With this approach, radiation effects on polymers can be followed.

In a flexible network system, such as a partially cured rubber, the T_2 , or spin-spin, relaxation time exponential decay curves display components characteristic of the crosslinked and noncrosslinked fractions. The entanglements are included in the crosslinked component and form a dynamic

nonpermanent network. The lifetime of entanglements decreases as the temperature is raised. The effect of temperature on T_g can therefore be used to distinguish the permanent crosslinks from entanglements.

Some interesting and unexpected results have emerged from the pulsed NMR studies. In certain polymers, such as polyethylene, above the melting point there remains a residual memory of the molecular orientation and arrangement in the solid state. With rubber, the dependence of the T_g relaxation curve on temperature and concentration is similar to that of the viscosity; the constants are directly related to those derived from viscoelasticity. Rheological behavior can therefore be studied using pulsed NMR. With rubber, both T_g and the viscosity depend primarily on the free volume modified by temperature or concentration. The behavior of carbon black or other fillers in long chain polymers can be assessed. Charlesby's present results indicate that the reinforcing effects are not due to increasing "crosslink" density. Finally, the method can be used to evaluate the effects of so-called radiation protectors on biological systems.

For many years, P. Fydelor, K.V. Lovell, L.B. Adams, B.J. Ringrose, G. Partridge, and coworkers have had an extensive program in radiation grafting to produce separators for alkaline batteries. Acrylic acid is radiation grafted to a number of polymer films--mainly polyethylene, but also polypropylene, nylon 12, and polytetrafluoroethylene. The method is to immerse the films in an aqueous solution of acrylic acid and irradiate in a cobalt-60 source; 4.3-MeV electrons also have been used.

To prevent excessive formation of polyacrylic acid in the aqueous solution, water soluble inhibitors were used; ferrous sulfate and potassium ferricyanide were particularly efficient. The rigorous exclusion of oxygen was not necessary. Film thicknesses from 0.015 to 0.050 mm have been used. Earlier details of the preparation and performance of the separators have been published in Power Sources, Vol 3 (1971), pp 327-348 and Vol 4 (1973), pp 141-161 (Oriel Press Ltd.), and in Vol 7 (1979), pp 1-23 (Academic Press Inc.).

A pilot plant yielding samples 0.6-m wide and 250-m long has been constructed. The process has been patented, and industrial exploitation can be anticipated. An up-to-date report of the development and use of graft copolymer separators for alkaline

batteries will appear shortly in a paper by K.V. Lovell and L.B. Adams, Journal of Power Sources, Vol 9, No. 2 (1983), pp 101-135.

Fydelor and Ringrose have also developed the radiation grafting of acrylic acid to polymers to confer biocompatibility. High and low density polyethylene, polypropylene (dense and microporous), and tetrafluoroethylene were selected as substrate films. The grafting method was similar to that used for battery separators. The grafts were essentially homogeneous with hydrophilic and hydrophobic domains. The techniques can also be applied to tubular materials. Biocompatibility is at least as good as the best commercially available materials. Applications now being actively explored are for implant materials, for possible vascular prostheses, and for dressings, especially in the treatment of skin loss and open wounds. Patents will shortly be issued, and additional information will be reported in a future ESN.

In nonradiation polymer research, K.J. Randle has developed the use of laser light scattering "photon correlation spectroscopy" (PCS) to measure the average size of latex particles. The size can be measured at a single angle in a time scale on the order of tenths of seconds. The results have been combined with conventional light scattering and transmission electron microscopy to study emulsion polymerization problems.

Styrene was the monomer used and potassium persulfate the initiator. Particle nucleation, flocculation, and growth in an emulsifier-free system of styrene in water was investigated first. It was shown that the imbibing and polymerization of monomers in the initial particles destabilized them, causing flocculation and coalescence. The process of aggregation of particles was also followed using PCS with an emulsifier-free system. PCS was valuable for studying the early stages of emulsion polymerization. An earlier summary of the PCS method was presented by Randle in Chemistry and Industry (1980), pp 74-81. Randle and Adams are extending the work into actual latex preparations, some of which may be studied as nonmigratory binders for activated charcoal and other sorbents for clothing used to protect against chemical and other agents.

Fydelor and Lovell have started a program funded through C.D.E. (Chemical Defence Establishment) Porton to study novel composites for clothing used as protection against chemical, biological, and other agents, and the present status

of clothing for chemical warfare is being evaluated. In particular, problems connected with the physiological load, sweat, and solute poisoning of activated charcoal and other features will be investigated. Fydelor and Lovell hope to study sorbents other than activated charcoal.

V.T. Stannett

COMPUTER SCIENCES

COMPUTER SCIENCE AT OXFORD UNIV.

Oxford Univ. has a postgraduate Department of Computer Science but no undergraduate program. Computer science education and research is within the Faculty of Mathematics. Degrees of M.Sc. in Computation and of D. Phil. in Computer Science are given by the university; there are 13 candidates for the D. Phil. degree and 16 in the M.Sc. program.

The Computer Science Department consists of three permanent faculty members and 10 research officers under contract. Most of the contract work is funded by the UK Science and Engineering Research Council (SERC). There are, however, several collaborative efforts under way with industry: IBM, ICL, and GEC.

The department has two major programs, software engineering and distributed computing. During a visit to Oxford Univ. the author was given an overview of the computer science activity by Dr. Stephen Schuman and a more detailed discussion of the work in robotics by Dr. W.F. Clocksin.

Software Engineering

The faculty believes that the most pressing problem in the next 20 years will be the reduction in the cost of computer software to match the reduction in hardware cost. The problem needs to be approached through improved education, tools, and hardware.

Current work in the software project can be summarized as follows:

- Development of mechanized tools to support the specification and development of systems.
- Continued application of current specification and development methods to realistic problems from industry.
- Continued use of existing methods of technology transfer, collaboration with industry and publication of

designs, and specifications in familiar applications areas.

• Enhancement of the existing conceptual tools.

An example of software engineering work at Oxford is given in a paper by B. Sufrin entitled "Formal Specification of a Display-Oriented Text Editor." The text editor was designed to be easy to use on inexpensive hardware.

The specification is not intended to be a direct blueprint for an implementation but rather to give an indication of what the editor is to do and how it is to do it. The entire design is intended to allow an author to use the editor while concentrating on the composition of a document rather than on the complexities of the editor interface.

Most commands are invoked by a single keystroke, and the interpretation of every key on the keyboard is fixed. There is no dependence on non-visible aspects of the history of the edit session. Rather than being complicated sequences of keystrokes that must be consciously considered, the commands are author oriented. Thus, many common editing actions can become reflexive.

The specification is in three main sections: first, the specification of a document editing subsystem is given; then a document display subsystem is specified; finally, the desired relationship between the two components is given, and a modularization for implementations is suggested. Detailed properties of display devices are not given; editor commands are explained solely as transformations on documents. In summary, the role of the display subsystem is to keep in view the region of the document that surrounds the cursor. The abstraction chosen as the basis for the model of a display device is a rectangular screen on which characters appear. The abstraction can be implemented on a wide variety of display devices.

The specification of the editing subsystem is presented in stages; at each stage a mathematical model is presented. It is powerful enough to capture the design decisions to be illustrated and to define an editor, giving theorems that indicate its important properties.

Distributed Computing

The primary aim of the distributed computing project is to make the programming and application of multiple microprocessor networks as simple and as natural as the programming of a single microprocessor work station is now. Each user should be able to write a

program that uses any number of the available processors. The UCSD-Pascal program development system will be used as a development base, either through extending the system or replacing parts of it to achieve the goal.

The secondary aim is to incorporate into the software system other improvements needed to facilitate its distributed use. The aim is also to investigate and assimilate the technology which underlies the development and propagation of low cost, high quality software.

The work will be carried out on a number of LSI-11 microprocessors connected by a Cambridge Ring, so that results can be made available to participants in the Distributed Computing Systems Program. As UCSD-Pascal is machine independent, the results of the research should be of use with other hardware.

A doctoral thesis completed in 1982 by L.P. Fertig illustrates some of the work being carried out in distributed computing. Fertig set out to explore an integrated design technique for a system in which the simulation and distributed implementation may be viewed as two alternative realizations of the same program.

The language used as a starting point was Pascal-Plus. The language had to be extended slightly so that hardware implementation of distributed systems could be fully defined. The extended language has been called Distributed Pascal-Plus (DPP). A technique was developed to allow a DPP program to be compiled into code for a network of processing elements. DPP modules which--in the simulation program--model the environment of the system to be built, may be called hardware modules. A hardware module is compiled into code to interface to the external hardware simulated by the module. Thus, interfacing a system to external hardware consists of writing a program module that simulates the hardware and declaring it as hardware. The compiler generates codes for an appropriate hardware interface from the text of the hardware module.

Two real-time constraints can be imposed on DPP program modules: time limits on the execution of code and on functional remote communications. In the former case the expiration of the time limit is considered so serious that it must cause a catastrophic failure of the module. This is because the time limit is considered a part of the specification of the program module. In the latter case, the expiration of the time limit causes an explicitly stated default value to be inserted in place of the remote value.

A hypothetical safety system for a nuclear plant was simulated in Pascal-Plus, and the simulated program was extended to DPP by the addition of necessary implementation details. Fertig's thesis then discussed and evaluated the hardware system that would result from a compilation of the program.

Robotics Development

The robotics project is in the Faculty of Engineering, St. Cross College. The main project is sensory control of robot arc welding of thin sheet steel pressings. Conventional robots are seldom used for Metal/Inert-Gas (MIG) arc welding on thin (1- to 2-mm) sheet steel pressings because maintaining accurate fit-up and fixturing is difficult. Dimensional variations are introduced by wear of tools and fixtures, effects of variable spring-back in pressings, and thermal distortion during welding. Such variations cause errors of as much as ± 3.0 mm in the position of the welding torch relative to the seam. For good welds the error should be reduced to within ± 0.5 mm. The objective at Oxford is to reduce the error by using sensory feedback to control the position of the torch relative to the seam. Gap width must be sensed in order to change welding parameters and strategies.

The development system consists of a conventional robot equipped for MIG welding, a control subsystem, and a vision subsystem. An IRb-6 industrial robot made by ASEA, a Swedish robot company, is now used; it has five degrees of freedom and a payload of 6 kg at rest. The IRb-6 is equipped with an Aga MIG welding set, and both robot and set are controlled by the standard ASEA controller containing an 18008 microprocessor. Minor interface modifications have been made to the welding set and 8008 program.

The control subsystem consists of an LSI-11/23 which is connected to the ASEA controller by a 9600 baud serial line. The control subsystem has a kinematic coordinate conversion capability to permit programming and executing ASEA programs in several different Cartesian coordinate systems. The system works in real time and does not cumulate errors over successive forward and inverse conversions. It deals with arbitrary offsets of multiple tools about the wrist, is easily calibrated by the user, and permits arbitrary geometrical transformations and the following of arbitrary space curve paths, interpolating in world coordinates. The control subsystem also deals with

arbitrary transformations between image coordinates and corresponding robot joint coordinates.

The sensory system consists of a PDP-11/23 computer with a sensor and interface. The sensor consists of a rectangular array camera, a GaAlAs infrared laser diode emitting at 830 nm, and a narrow band optical filter. The camera generates a video signal that is digitized and stored as a 256 x 256 array of eight-bit pixels. A line 10-pixels long subtends about 1 mm on the focused inspected surface. The sensor assembly is fixed to the end effector of the robot, near the welding torch. Fitting the camera with a narrow band optical filter having a spectral halfwidth of 10 nm centered over 830 nm effectively removes much of the visible arc emission from the image.

The sensor operates on the principle of active triangulation ranging. The laser diode emits through a narrow slit and cylindrical lens to cast a sheet of light on the workpiece. The intersection of the light sheet and the workpiece surface, when viewed from a different aspect with the camera, forms a curved or straight-line stripe that depicts the layout of a particular cross-section of the surface relief of the workpiece.

The apparatus is used to improve the conventional robot teaching welding sequence by performing the following steps:

1. Manual teaching of weld seams on a preproduction master assembly.
2. Automatic visual survey of taught points on the master assembly.
3. Welding with visual correction of taught points and welding parameters.

The software for the sensor subsystem is written mainly in Pascal. The Pascal compiler generates PDP-11 machine instructions, but about 10% of the system is hand coded in PDP-11 instructions to decrease the time for image processing.

The system has been tested on more than 100 different images. Workpieces with a variety of joints have been used, all constructed with thin planar sheet steel pressings from 1- to 2-mm thick. Standoff and lateral errors of ± 3 mm are regularly corrected to within ± 0.3 mm, and about 20% of the cases are corrected to within ± 0.1 mm.

J. F. Blackburn

ELECTRONICS

PLESSEY LEADS UK GaAs EFFORT

To avoid the Blitz of World War II, Plessey Research (Caswell) Ltd. moved some 70 miles northwest of London to a rural setting near Towcester, where modern semiconductor research, development, and production facilities have been built. Construction has just begun, however, on a new 30,000 sq ft facility to house silicon semiconductor-related research. The building will be ultramodern in architecture, and will incorporate the most modern silicon processing and clean room facilities.

The new facility is the beginning of a 5-year building program. As the present silicon facilities are vacated, they will be razed to provide space for a new gallium arsenide (GaAs) semiconductor building. The present GaAs facilities, in turn, will be razed for a modern research and development (R&D) facility devoted to new semiconductor materials.

Plessey Research is virtually autonomous, has 550 employees, and reports directly to corporate management, which provides approximately 40% of the organization's operating funds. About 45% of the organization is included in the Silicon Integrated Circuit Group, which is responsible for R&D in N-channel metal oxide semiconductors (NMOS), complementary metal oxide semiconductors (CMOS), and high speed bipolar and surface acoustic wave (SAW) devices. The remaining 55% is the Solid State Research Group (SSRG), headed by G. Gibbons. The group is primarily involved in III-V semiconductor work.

Both groups support the corporation's three operating divisions: Plessey Electronic Systems Ltd. (PESL), Plessey Engineering and Components, and Plessey Telecommunications and Office Systems Ltd. (PTOSL). It is from these three divisions and government contracts that Plessey Research derives the remaining 60% of its operating funds. Of the three operating divisions, PTOSL is now growing most rapidly. PTOSL has recently formed a joint venture corporation with Scientific Atlanta (US) to take a strongly competitive position in the information transmission (IT) explosion widely expected to happen soon in the UK.

Electro-optics

Fifty people within SSRG form the electro-optics (EO) section. The group has three metal-organic-chemical-vapor-deposition (MOCVD) reactors (or "kits"

as they are known in the UK) for research, development, test, and evaluation (RDT&E), as well as pilot production of the GaInAsP light emitting diodes (LEDs) used in fiber optic communication links. Plessey was a major contributor to the London-to-Birmingham link of eight fibers in one cable. It is a multimode system now using one of its eight installed fibers and operating at 34 megabits/second. By June 1983 four of the eight fibers will be in operation, and the expected data rate will be 140 megabits/second.

Using a hydride reactor, the EO section is developing single mode 1.3- μm GaInAs injection lasers for use on a 54-km Liverpool-to-Preston fiber optic communication link that will be installed soon. The technology in the venture uses a lattice constant/bandgap grading approach to grow the GaInAs active region heteroepitaxially onto GaAs substrates.

Recognizing that the 1.3- μm operating wavelength is not the lowest loss portion of the spectrum in which to operate, the EO section is developing GaInAs injection lasers that operate at 1.6 μm and whose active semiconductor material can be directly grown on indium phosphide (InP) substrates. The procedure will eliminate the tedious and often strain-producing lattice constant grading required during epitaxial growth. In addition to the discrete 1.6- μm transmitters, the EO section is working on compatible nonavalanche photo diode detectors using field effect transistor (FET) post detection amplification. The most ambitious work within the EO section is that of a monolithic transmitter module operating at 20 megabits/second.

In a departure from the main thrust of fiber optic communication links, the EO section is also active in development of a dense photochromic read-write memory. While many schemes have been proposed for massive, dense archival memories (e.g., gigabyte size), they are of the write-once variety, and their contents cannot be modified once written. Plessey is taking a new approach, which not only retains the high density, large capacity, nonvolatility, and rapid read and access capabilities expected of such memories, but also provides for erasure and multiple write operations.

The basis of the approach is photochromics. Materials such as tungsten trioxide are colorless in their quiescent state but change to a color (e.g., deep blue) after being subjected to an electric field. The exploitable efficacy is their color retention after removal of the electric field (i.e., a

latching effect). An application of an electric field pulse of reverse polarity erases the effect and returns the material to its colorless state.

Other photochromic materials experience a change of their optical index of refraction when subjected to certain energy levels. As an example, the "write" signal may be ultraviolet light, the "erase" signal visible light, and the "readout" probe an infrared signal. Memories built on these phenomena offer virtually all of the properties required of archival memories. Plessey is concentrating its effort on the change-of-refraction-effect device. Although writing speed tends to be quite slow, access/read operations consume less than 100 nanoseconds. From a military perspective, the memories are not volatile in power line interruptions, but they are probably vulnerable to wipe-out by x-rays or gamma rays.

As most of the applications for electro-optics are expected to be commercial, the EO section receives most of its R&D funding from the corporation. The only other field of significance addressed by the EO section is SAW devices. Current work involves the use of an electron beam lithography system to define transducer arrays of 0.4- to 0.5- μm "finger lengths" on lithium metaniobate. Plessey intends to use the SAW devices for a high frequency Bragg spectrum analyzer.

Two-Terminal Devices

Two different approaches are being pursued in two-terminal microwave/millimeter wave device work. The first uses silicon impact avalanche transit time (IMPATT) devices. Although Plessey has developed and characterized devices over the 30- to 300-GHz spectrum, the 80- to 90-GHz region is emphasized. Plessey currently holds the world record for efficiency in converting direct current (DC) power to millimeter wave power in the lower portion of the spectrum and at 2- to 3-W peak power. (Hughes Aircraft holds the maximum power records.) Plessey is attempting to improve its IMPATT peak power achievements by bonding its devices to diamond heat sinks. Current achievements yield 0.5 W continuous wave (c.w.) at 90 GHz.

The second approach uses InP-transferred electron (GUNN) devices. Plessey's work here is directed toward 100- to 200- GHz oscillators, and 20- to 100-GHz reflection amplifiers for electronic countermeasures (ECM), mm\, radar, and communications applications. One such project seeks a traveling wave tube driver providing 100- to 150-mW

output power and 12-dB noise figure in a three-stage device.

Three-Terminal Devices

Work in three-terminal devices is mostly that of depletion mode GaAs FETs directed toward monolithic phased array components and monolithic satellite receiver components. In both low noise narrow band and in low noise broadband work Plessey's effort is very comprehensive. Achievements in low noise amplifiers are noted in the following table:

| | |
|---------|---------------------------|
| 2-4 GHz | <1 dB noise figure (N.F.) |
|---------|---------------------------|

| | |
|---------|-------------|
| 4-6 GHz | 2.5 dB N.F. |
|---------|-------------|

| | |
|------------|-------------|
| 8-10.5 GHz | 3.5 dB N.F. |
|------------|-------------|

| | |
|-----------|-------------|
| 10-13 GHz | 3.5 dB N.F. |
|-----------|-------------|

The 8 to 10.5 GHz amplifier was developed for Westinghouse (US). The table below denotes broadband amplifier developments completed to date:

| | |
|-----------|----------------|
| 0.1-1 GHz | Direct coupled |
|-----------|----------------|

| | |
|-----------|----------|
| 0.1-6 GHz | Feedback |
|-----------|----------|

| | |
|------------|----------|
| 0.1-14 GHz | Feedback |
|------------|----------|

| | |
|----------|----------------------------|
| 8-12 GHz | Conventional balanced amp. |
|----------|----------------------------|

| | |
|----------|----------------------------|
| 6-18 GHz | Conventional balanced amp. |
|----------|----------------------------|

Departing from the current US distributed approaches to broadband monolithic amplifiers, Plessey had experienced early encouraging results with a traveling wave transistor amplifier. The simple expedient of periodically adding capacitance is used to maintain equal phase velocities along the gate and drain "busses." The gate buss is actually integral to the gate itself and has a cross-section fashioned in the form of a mushroom. This single 1.0- μ m gate structure traverses the entire 1.2-mm length of the traveling wave transistor. It is fed at one end and resistively loaded at the other. Plessey anticipates UK Ministry of Defence (MoD) funding to develop the device further. A balanced amplifier structure is contemplated with two parallel gates being fed 180 degrees out of phase.

Plessey is quite active in discrete GaAs FET R&D. Having set an objective for a 40-GHz, solid state, three-terminal amplifier, Plessey has achieved 3.3 W at the 1-dB gain compression point when operating at 8 GHz and achieving a 30% power-added efficiency. By shrinking the overall device from four cells of 600- μ m each to three of 1.2-mm each, occupying the same area as the small gate peripheral device, and using a "sparse via" source grounding technique, Plessey hopes to achieve 2-W c.w. at 18 GHz. A two-cell part of the above design has already achieved 1.25 W with 6-dB linear gain at 14 GHz. It used

0.9- μ m gate lengths and vapor phase epitaxy (VPE) technology. By using submicrometer gates defined by electron beam lithography, further increases in upper frequency response are expected.

A unique approach is being investigated in the quest for 40-GHz FET amplifiers. Initial work has been directed toward devices having electron-beam-defined and recessed gates only 0.3- μ m long and 50- μ m wide. Two-cell devices were fabricated on VPE material, and the substrates were thinned and bonded to quartz to reduce losses; they exhibited rather impressive characteristics. The maximum stable gain achieved was 12 dB at 22 GHz, 7 dB at 30 GHz, and 5 dB at 40 GHz. At 32 GHz, the devices exhibited a noise figure of only 3.5 dB with an associated gain of 5.75 dB. At 14 GHz the N.F. was 1.2 dB. Channel doping was $4 \times 10^{17}/\text{cm}^3$, and the gate material was aluminum.

In monolithic R&D, current efforts include a 0- to 4-GHz video amplifier (ECM oriented) and a two-stage, low-noise, X-band (10.5- to 13-GHz), direct satellite broadcast receiver that features polyimide material for both parallel plate capacitors and crossover insulators. Still other monolithic developments include a 0.1- to 6-GHz low noise amplifier and a C-band power divider and phase shifter. In monolithic amplifiers, Plessey has developed a sputter process for depositing CrSiO cermet resistors. It is interesting that the specific resistivity depends on the Cr:Si ratio. Between 40 and 65% Cr, the resistivity changes by a hundred-fold. For satellite applications, monolithic developments are under way for a 17-GHz double downconverter superhet receiver and for a satellite switched time domain multiple access communications system. Both the X-band amplifiers and the baseband video amplifiers will be of GaAs. The system is intended to be able to time multiplex many pencil-shaped electromagnetic beams to earth.

Semiconductor Materials

M. Cardwell and I. Sanders have recently completed some interesting characterizations of GaAs and InP materials that may affect a large portion of III-V semiconductor work worldwide. Using liquid encapsulated Czochralski-grown GaAs boules, Cardwell and Sanders sliced wafers across <110> diameters with <001> normals. High spatial resolution near-infrared absorption techniques have been used to correlate increased absorption at 1.0- μ m illumination with regions of high dislocation density. The regions appear

as the roots of a tree in the $\langle 110 \rangle$ plane and correspond to the cellular dislocation structures commonly observed in the $\langle 100 \rangle$ plane.

Cardwell and Sanders have further correlated the regions with regions exhibiting EL2, the electron trap located 0.75 eV below the conductor band edge. The exceptionally high resolution of better than 0.2 μm was achieved by scanning a narrowly focused beam of radiation emitted from the monochromator of a Pye-Unicam SP-700 spectrophotometer and by viewing the radiation transmitted through the wafer by a CCTV silicon vidicon. To eliminate any possible interference by surface damage, scans were also made at 2- μm wavelength; elaborate precautions were taken to avoid work damage effects from wafer cutting and polishing. The Plessey EO group is now convinced that the EL2 centers are associated with antisite defects and the dislocation climb process. The work will soon be published in *Applied Physics Letters*.

Using the same approach, the group observes similar effects in InP. It has been determined that the "grappes" phenomena in InP (after the French observers who reported grape-like clusters of defects in InP material) result from the same antisite defects and dislocation climb processes observed in GaAs. There is, however, an extremely important difference. The Pauli radii of Ga and As are similar, but those of In and P are quite different. As a result, antisite defects in the InP dislocation climb process do not anneal out, and massive misfit dislocations result in InP and lead to the grappes. In LEDs or injection lasers fabricated from InP, the location of grappes within the laser region creates a dark spot within the light beam, resulting in greatly reduced efficiencies. Even worse, using cathodoluminescence measurements, Plessey determined that massive misfit dislocations propagate into any material (including GaInAs) grown epitaxially on the InP substrate; Plessey has abandoned virtually all InP-related device programs except those for GUNN and IMPATT devices. There is, of course, conflicting evidence by others regarding the propagation of substrate dislocations into the epitaxial films. If the dislocations can be prevented from propagating, or if an economical and truly grappes-free growth technique can be found, then the Plessey decision may have proven to be premature.

Summary

Plessey is the largest UK producer of III-V semiconductor devices. The

company has an aggressive 5-year program of building and R&D facilities expansion to maintain its lead in the field. The corporation's major interest appears to be IT--an area in which Plessey has formed a joint venture subsidiary. Recent research findings regarding the fundamental vulnerability of InP devices has led Plessey to abandon all MOS FET work and LED/laser work in InP-based devices.

M.N. Yoder

SCIENTISTS MEET TO IMPROVE SEMICONDUCTOR SURFACES AND INTERFACES

In very large scale integration (VLSI) of circuits, semiconductor geometries are approaching micrometer dimensions. Consequently, electric current densities exponentially increase, as do the requirements for reproducibility (yield) and reliability.

For several years semiconductor manufacturers have realized that the traditional aluminum metal contact to semiconductor surfaces can no longer do the job. Thus, support for surface science has increased; new analytical techniques and equipment have been developed, more scientists have become involved, and interdisciplinary approaches directed towards common objectives have been accepted. Although much of the research is done in the proprietary laboratories of semiconductor manufacturers, there is a growing realization that no one organization will find all solutions, and that maximum progress will result from cooperation that encourages both critical analysis and open discussion.

The importance of surface science has been recognized on a national scale in Japan, where the government has recently established an engineering research association devoted to the surface science of semiconductors. The Ministry of Trades and Industry (MITI) funds 60% of the work, while the semiconductor industry supplies scientists and the rest of the funds. The group works in the Optoelectronic Joint Research Laboratory in Kawasaki. Fundamental knowledge gained is shared among the Japanese participants.

The "2nd Trieste IUPAP Semiconductor Symposium" has helped create an interdisciplinary approach to sharing and critically analyzing surface science work worldwide. Scientists from 21 countries attended. The meeting was sponsored by the International Union of Pure and Applied Physics (IUPAP) under

the auspices of the Italian Ministry for Scientific Research, and was supported by the Italian National Research Council, IUPAP Semiconductor Commission, IBM of Italy, US Office of Naval Research, and the International Center for Theoretical Physics (ICTP), which also served as the host facility. The ICTP was founded 25 years ago by Nobel laureate A. Salam, who wanted to establish a facility where scientists from around the world could come to study, teach, and share their findings.

The symposium was purposefully structured to avoid parallel sessions and thus foster an exchange of information across the scientific fields of surface chemistry, surface physics, crystallography, interface physics, heterojunctions, and charge carrier propagation in ultra-small confined structures.

The Silicon Surface

About 90% of worldwide capital investment in semiconductor research, development, test, and evaluation (RDTE) and production facilities is silicon-oriented. Silicon accounts for a similar dollar fraction of semiconductor sales and for over 97% of all semiconductor devices manufactured. The production yield of silicon devices--especially the metal-oxide-semiconductor (MOS) devices--is critically dependent on the preparation and control of the silicon surface. The profit incentive for high yield has stimulated an enormous amount of research directed towards gaining a better understanding and control of silicon surface properties.

Using electron bombarding energies in the 2- to 10-eV range and incident at an angle of 70 degrees from the silicon surface normal, H. Wagner of Kernforschungsanlage, Jülich, FRG, has improved a surface analysis technique known as high resolution electron energy loss spectroscopy (HREELS). In a high vacuum chamber, secondary electrons are analyzed for direction and energy. Wagner has found that water on the silicon surface disassociates at 700°C, freeing oxygen, which, in turn, bonds to the silicon surface.

P. Citrin of Bell Laboratories analyzed interference patterns between the outgoing nuclear core signals and those backscattered by adsorbed surface atoms. He uses a much-improved surface electron x-ray auger Fourier spectroscopy (SEXAFS) technique; an x-ray beam and an electric field are applied

mutually orthogonally to the silicon surface. The interference patterns obtained are correlated with distance; Citrin claims 0.02- to 0.03-angstrom precision in measuring atom-atom bond lengths. He has investigated tellurium, indium, and chlorine adsorbates on silicon, germanium, and copper. Not only does Citrin set new records for precision of length measurement, but he also can determine the bonding angle. He finds that the bonding distances increase in direct proportion to the bond ionicity.

N.M. Amer (Univ. of California, Lawrence Berkeley Laboratories) discussed a novel technique for surface analysis using optical absorption. To overcome previous problems associated with optical absorption experiments, Amer uses a pump laser to heat the surface and a probe laser to measure. Using the apparatus shown in Figure 1, he can measure the change in the optical index of refraction, and for the first time can separate optical absorption from optical attenuation. The technique provides an additional degree of freedom not available before. The pump laser creates local heating, which produces a very small (e.g., 0.01 angstrom) bump. The size of the bump is correlated with the absorption coefficient and is determined to within one part per million. Amer plans to use the new analytical capability to examine surface states on silicon.

Various papers considered the reconstruction of a virgin silicon surface obtained by cleaving in ultra-high vacuum. Although a great deal of work is being done in the field, there is little correlation of results among experimenters.

Ohmic Contacts

Although the transition metal silicides are known to be much more stable than aluminum contacts, reproduction has been a problem. In the case of cobalt silicide, Co_2Si , CoSi , or CoSi_2 , may form. These compounds are representative of most of the metal silicides. There have been various hypotheses about which compound will be favored during the formation and during subsequent processing. The most popular suggestions have been that the most stable compound grows at the expense of others, the compound first nucleated on the surface will predominate, and the deposition rate is the most influential factor.

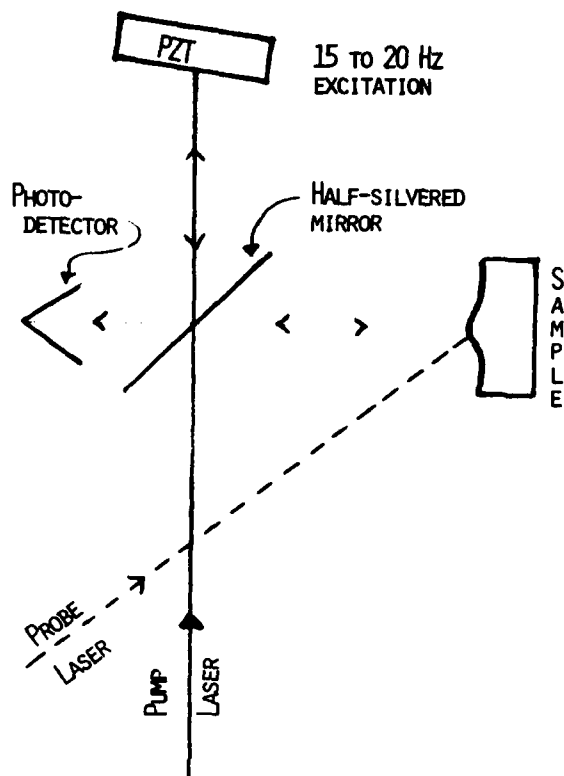


Figure 1. Surface optical analyzer.

G. Ottaviani of the Univ. of Modena has ruled out all three hypotheses and has developed a very simple theory. If the stoichiometric ratio of silicon to metal is one, then the compound formed is MSi , where M is the transition metal. If M exceeds Si , M_2Si will form. Conversely, if Si exceeds M , then Si_2M will form. His experiment was equally simple. Stoichiometric ratios of M and Si were deposited, and MSi was formed. If the MSi films are in contact with neither Si nor M when brought to elevated temperatures, they remain stable. If they are overlaid with metal films, they convert to M_2Si at elevated temperature. Conversely, if overlaid with silicon, they convert to MSi_2 . MSi films deposited on Si and overlaid with metal appear to be most stable in the practical application.

Other symposium participants pointed out that a stable phase of the silicide was insufficient to ensure a contact both reproducible and of high quality. The additional requirement imposed is that the silicide be

epitaxially grown. Even if deposited under lattice mismatch strain, the properties of an epitaxial contact are better than those of a nonepitaxial contact.

Metals other than the transition metals on silicon are not so well behaved. Several speakers reported on cluster nucleation and formation of silver (Ag) on Si accompanied by erratic diffusion. E. Suliga of The Univ. of Hanover has studied the diffusion of Ag on $[111]$ germanium (Ge). He finds that the crystallographic orientation of the Ge crystal must be within 0.3 degrees of normal to obtain reproducible Ag diffusion. He related any misorientation to steps on the crystal surface permitting fast lateral diffusion. This newly discovered requirement of alignment accuracy may explain previously conflicting data.

III-V Semiconductors

Although silicon-related topics accounted for most of the papers, some significant findings relating to the gallium arsenide ($GaAs$) surface were reported. R. Heckingbottom of British Telecom has completed impurity doping efficiency experiments in molecular beam epitaxy (MBE) grown $GaAs$. He found that column VI donor element impurity incorporation efficiency was significantly reduced when the $GaAs$ crystal was slightly As-rich. Under the same As-rich conditions, magnesium acceptor doping efficiency was significantly enhanced.

Another noteworthy finding concerned the junction-associated surface recombination velocity (SRV). Such surface recombination velocity accounts for unproductive current paths, nonradiative losses, and decreased device lifetime because of defect creation, defect migration, and induced chemical reactions. Recent widespread activity in $GaAlAs/GaAs$ heterojunction transistors for use in microwave devices and radiation-hard gigabit logic is in jeopardy because of adverse SRV. D. Aspnes of Bell Laboratories has found two solutions. First, he finds that indium phosphide surfaces are 1,000 times less influenced by SRV than are $GaAs$ surfaces, and, more practically, he finds that as little as one-third monolayer of ruthenium deposited on the $GaAs$ surface virtually eliminates the problem.

Summary

During the past few years new analytical tools have enabled a rather detailed atomic scale understanding of semiconductor surfaces and of

chemisorbed monolayers on such surfaces. Unfortunately, there is still no universal correlation between these properties and the electronic properties of the surface.

K.N. Yoder

MATERIAL SCIENCES

METAL PHYSICS AT GÖTTINGEN

The Institut für Metallphysik der Universität Göttingen, Hospitalstrasse 12, D-3400 Göttingen, FRG, is a leading international center for basic research in materials science. (see "Werkstoffkunde in Niedersachsen [Lower Saxony]," by J. Perkins, ESN 33-6:232-237 [1979]). Professor Peter Haasen, member of the US National Academy of Engineering, is director.

I first visited the institute in 1964, when Michael Ashby, professor of engineering and FRS at Cambridge, was a postdoctoral fellow doing research on precipitation strengthening of single crystals with Haasen and R. Ilschner, now Professor at Erlangen. Current visiting scientists are F.-W. Zhu, Beijing Institute of Iron and Steel Technology, People's Republic of China, and W. Szkielko, Poland.

Haasen is involved in four research areas: atomic microstructures (precipitation hardened alloys, spinodal alloys, and metallic glasses); deformation of polycrystalline ionic materials; grain boundaries in semiconductors; and recrystallization of metals. H. Teichler is doing theoretical work on diffusion, and Th. Hehenkamp is doing research on diffusion in alloys, material transport, point defects in alloys, thermodynamics, and x-ray microanalysis. Earlier activities on crystal growth and electrical properties of dislocations have spun-off to the nearby Kristall-Labor der Physikalischen Institut, headed by H. C. Freyhardt, and the Physics Institute IV, Semiconductors, under W. Schröter. The broad spectrum of Physics Institute activities at Göttingen, from I. Low Temperature to IX. Astrophysics, was mentioned in "Third Physics Institute at Göttingen," by A.B. Focke, ESN 24-10:313-315 (1970).

Freyhardt has research interests in nonequilibrium states (in condensed phases) and in microcomposite superconducting materials, including stoichiometric effects on compounds such as

$\text{Sn}_x\text{Mo}_y\text{S}_z$. He is editor of the book series Crystals: Growth, Properties and Applications, Springer-Verlag, Berlin. Following up his work with Haasen, Schröter has been involved in theoretical research on the electrical properties of dislocations in semiconductors (and ionic crystals). Deep-level transient spectroscopy (DLTS) measurements are of interest in Ge, Si, and CdTe crystals. A major consideration for photovoltaic cells is quantitatively to separate the effects of dislocations and impurities in DLTS and other measurements. The latest work indicates that detailed characterization of the form factor is a promising method of distinguishing between the two effects. Schröter has been working with G. Champier's group at Laboratoire de Physique du Solide, ENSMIM, Nancy, France (see ESN 36-11:299-300 [1982]).

Atomic Microstructures

The atomic microstructures research is an interesting combination of established mechanical property studies, transmission electron microscopy (TEM) expertise, and new studies with atom probe field ion microscopy (FIM) whereby individual atoms are chemically identified among hundreds observed in a single field of view. Alloys of Ni-Al, Cu-Fe, Cu-Ti, and Cu-Ni-Cr have been studied. For a Ni-15.4% Al alloy, dark field TEM observations have been made of the earliest stages of precipitation of Ni₃Al particles with radii of 2 to 6 nm in the Al-containing Ni matrix (see M. Gröblich, P. Haasen, and G. Frommeyer, Scripta Metallurgica, 16 [1982], pp 367-370). Atom probe FIM and neutron small angle scattering measurements are to be determined on the same alloy in a cooperative project with researchers at the Max Planck Institut für Metallforschung, Stuttgart. Compression test measurements on the alloy appear to confirm the Labusch-Schwarz theory for the hardening of concentrated alloys, stemming from earlier theoretical work at Göttingen.

The atom probe FIM has been used by H. Wendt and R. Wagner to study changes in strengthening contributions from solid solution and precipitation hardening for dilute Cu (0.28 to 1.15 atomic percent)-Fe alloys (see Acta Metallurgica, 30 [1982], pp 1561-1570). FIM needle points were produced from 0.2-mm diameter wires and imaged with neon at 90°K to allow atomic discrimination of Fe atom clusters at dimensions on the order of 0.5 nm. Wagner, now at GKSS-Research Centre, Geesthacht and Sonderforschungsbereich 126, Göttingen-Clausthal, has published Field Ion

Microscopy, Vol 6, Springer-Verlag Series. Advances in microchannel electron multiplier arrays allow imaging of low melting point metals, including Al.

Other interests with atom probe FIM relate to fatigue studies of spinodally decomposed Cu-4 atom percent Ti and Cu-30% Ni-3.2% Cr alloys, to the brittleness of metallic glasses, and to the magnetic properties of Fe-Cr-Co alloys. Persistent slip bands are studied to gain an improved understanding of the fatigue behavior of single crystals and polycrystals. The effort at Göttingen is intended to relate scanning electron microscope observations with atom probe FIM analysis of the atomic microstructure. The Cu-Ni-Cr alloy, IN 732, was supplied by R.F. Decker and F.A. Badia (International Nickel Co., NY); the alloy has a grain size of about 8 microns.

The atom probe-FIM is nicely suited to studying the chemical inhomogeneity of metallic glasses on an atomic scale. Piller and Haasen reported such observations on $\text{Fe}_{40}\text{Ni}_{40}\text{B}_{20}$ in Acta Metallurgica, 30 (1982), pp 1-8. Phase separation of amorphous $(\text{FeNi})_{10}\text{B}$ and FeNiB compounds were observed in particles about 4.0 microns in size. Embrittlement occurred when particle radii of 2.0 nm and particle volume fractions of 0.3 were reached by annealing at temperatures as low as 280 to 350°C. F.-W. Zhu demonstrated the observation of domain structures in an Fe-Cr-Co alloy with the imaging atom probe-FIM method. The observations are to be correlated with neutron diffraction and Mossbauer studies.

Polycrystalline Ionic Solids

The polycrystal deformation behavior of ionic solids is now being studied at Göttingen as a natural extension of the single crystal studies done previously. A practical reason for the current work is the proposal to store nuclear wastes in geological salt domes. The brittleness of the enclosing material is an issue, especially the effect of thermal stresses and textural morphology; for example, US salt domes are composed of extruded basaltic materials.

One fundamental reason proposed for pure polycrystalline ionic solids showing brittle fracturing behavior stems from their limited number of deformation systems. W. Skrotzki, G. Frommeyer, and Haasen have discussed this consideration in "Plasticity of Polycrystalline Ionic Solids," Physica Status Solidi (a), 66 (1981), pp 219-228. Although five independent

deformation systems are generally considered sufficient for an arbitrary deformation without volume change at grain boundaries, Skrotzki et al. show that brittleness also requires cross-slip on the otherwise easy $\{110\}\langle 1\bar{1}0\rangle$ slip systems. The results are affected by the preferred crystallographic orientations of grains in extruded NaCl, KCl, KBr, and AgCl materials.

Experiments have been performed on rock salt from the Asse mine, FRG. Crystallographic textures were measured by neutron diffraction, and the slip band structures were studied by etch pitting. The results might be related to observations by C.M. Wu and R.W. Armstrong in the article "Lattice Misorientation and Displaced Volume for Hardness Indentations in MgO Crystals," Journal of the American Ceramic Society, 61 (1978), pp 102-106, which suggested that slip on $\{111\}\langle 1\bar{1}0\rangle$ systems is required to prevent dislocation-initiated cracking on $\{110\}$ at hardness impressions.

The total ionic deformation and cracking results described above, especially the newest ones at Göttingen, are refinements of ONR-supported research by R.J. Stokes and colleagues in the early 1960s. The current work includes comparison of single crystal and polycrystal deformation. The dependence of the anisotropy of single crystal hardness on temperature, divalent doping, and ionicity has been correlated with $\{110\}$ and $\{100\}$ slip by W. Skrotzki and P. Haasen in "Hardening Mechanisms of Ionic Crystals on $\{110\}$ and $\{100\}$ Slip Planes," Journal de Physique, Colloque C3, supplément au no. 6, c3-119 to c3-148 (1981).

Grain Boundaries in Semiconductors

Just as work at Göttingen has moved from single crystal studies to polycrystal ionics, so has research progressed from the properties of individual dislocations in Si, Ge, and other semiconductors to the atomic structure and properties of grain boundaries in semiconductors.

H.-J. Möller reported an extensive modeling investigation of " $\langle 011\rangle$ Tilt Boundaries in the Diamond Cubic Lattice," Philosophical Magazine, A43 (1981), pp 1045-1055. Boundaries in Ge bicrystals solidified from the melt were observed; the boundaries reconstruct themselves. Direct Phillips electron microscope images have been obtained at a resolution of 0.3 nm. The observations suggest that a high angle grain boundary may consist of two misorientation components: one large-angle part

composed of coincident site lattice positions and one small-angle part accounted for by crystal dislocations forming a sub-boundary (see R.G. Rosemeier, R.W. Armstrong, S.M. Johnson, G.M. Storti, and C.M. Wu, "Polycrystal X-ray Topography and the Photoresponse of Grains or Grain Boundaries in Polysilicon," Fifteenth IEEE Photovoltaic Specialists Conference--1981, pp 1331-1337). The interesting feature is that the crystal dislocation part of the boundary may be responsible for the total electrical properties.

Möller, now at the Technische Universität Hamburg-Harburg, did some of his research at the Department of Metallurgy and Materials Science, Case Western Reserve Univ., Cleveland, OH. The work related to recrystallization and grain growth in polycrystalline semiconductors. He plans to study sintering processes and laser annealing of polycrystalline semiconductors. Szkielko is continuing the work at Göttingen.

Recrystallization

The research activities on grain boundaries are also related to work at Göttingen on recrystallization. The specification of a critical nucleus for thermal transformation to a new grain structure of a cold-worked material is one topic of research. In collaboration with researchers at Stuttgart, Göttingen workers are applying high voltage electron microscopy (HVEM) to the observation of recrystallization nuclei within thick specimens of 99.9998% pure copper and 99.99% pure aluminum. The copper work has been reported in articles by P.-J. Wilbrandt and Haasen, "HVEM of the Recrystallization of Tensile Deformed <110>-Oriented Copper Single Crystals, Part I. The Deformed State," and "Part II. The Recrystallized State," Zeitschrift für Metallkunde, 71 (1980), pp 273-278 and 385-395.

The main result is that new grain orientations are accounted for by multiple annealing twinning steps occurring from the cold-worked single crystal orientations; thus, the recrystallized texture differs from the deformation texture. The recrystallization result seems to be related to the observation of grain orientations in polysilicon castings, whereby adjacent grain orientations are related by multiple twinning steps (see R.G. Rosemeier et al., "Polycrystal X-ray Topography and the Photoresponse of Grains or Grain Boundaries in Polysilicon," Fifteenth IEEE Photovoltaic Specialists Conference--1981, pp 1331-

1337.). Wilbrandt has reported on "The Limits of a Reliable Interpretation of Recrystallization Texture in Terms of Multiple Twinning" in Physica Status Solidi (a), 61 (1980), pp 411-418.

The aluminum studies are in progress; preliminary results seem similar to those obtained for copper. Impure material was selected to have a recrystallization temperature high enough to prevent in-situ recrystallization.

R.W. Armstrong

OPERATIONS RESEARCH

MANAGEMENT SCIENCE RESEARCH AT ODENSE UNIVERSITY

Odense Univ. occupies a new campus on the outskirts of Odense, Denmark. Although the school is of moderate size--about 6,000 students--it has an excellent Management Science (MS) Department which admits about 220 new students per year. While the department does not offer a PhD degree, there is a program leading to a degree that appears to be a compromise between an MBA and a PhD. Over half of the department's faculty members received doctorates from American universities. Perhaps this is why the faculty takes a very quantitative approach, which is somewhat unusual among such departments in Scandinavian universities.

B. Obel, chairman of the department, has been involved in a variety of research activities. One of his main interests is organization theory. With R. Burton (Duke Univ.), Obel has started using computer simulation experiments related to organizational behavior and organization structure. Computer simulation is advantageous because one can control conditions in an experiment and repeat the experiment so that the effects of changes in variables can be detected.

During a recent visit, Obel described the results of an experiment designed to test the "M-form hypothesis," and to compare it with the "U-form." A U-form organization is set up along functional lines, such as units concerned with sales, finance, and manufacturing; the U-form is thus organized by functional specialty. An M-form organization involves autonomous operating divisions. It is organized along product, brand, or geographic lines. In 1975, O.E. Williamson

formulated the "M-form hypothesis": a large enterprise organized and operated according to the M-form will favor more than a U-form organization the goal pursuit and least-cost behavior that help produce maximum profits.

In their study, Obel and Burton used what they call decomposed mathematical programming models to represent M-form and U-form organizational structures for various technologies. Obel believes that a problem with the various empirical studies of the M-form hypothesis is that they confound organizational structure and technology; with his simulation approach, he can control these factors independently. Thus it is possible, for example, to estimate whether organizational structure or technology has more influence on performance. Obel explained that he uses the term "technology" to refer to the physical methods used to convert resources into products. Technology can be described in terms of an input-output matrix. A "nearly decomposable" technology is one in which products and resources are not linked in a complex manner (i.e., the technology matrix is nearly diagonal).

The simulation experiments Obel and Burton conducted involved a design with the following independent variables: two types of structure (M-form and U-form) and two levels of decomposability of technology. The dependent variable is the rate of convergence toward optimal profits. The simulation involved generating random perturbations of the objective function and constraints in the each base model in order to represent random fluctuations in the firm's environment. Data from the experiment were used to test whether there are significant differences in performance due to variations in either of the independent variables.

A significant interaction between structure and technology was formed, so it was necessary to evaluate the effects of structural differences at each level of technology decomposability. At both levels, Obel and Burton found that performance with the M-form structure was significantly better than with the U-form structure. However, the difference in performance appeared to be more important for nearly decomposable technologies than for less decomposable ones. Obel concludes that the experiments support the M-form hypothesis.

L. Jennergren is interested in large scale systems and decomposition problems related to organization theory. As a United Nations staff member, he was recently involved in development of a global model designed to study

interactions between trade and development in the world economy. According to Jennergren, there seems to be a general opinion that the world economy in the coming decades will be characterized by slower growth and greater turmoil than in the past 25 years. The slowdown in production and trade, conditions of high inflation, and general operation of industry below capacity suggest that significant changes in the world economy may be taking place.

Global models can be used to study the possible causes of such changes and to design policies to effect recovery. Jennergren has been working with a global model he helped develop -- "DYNAMICO." The model uses linear programming and recursive techniques to trace alternative development "trajectories" for the world economy. Sublinear models are used for each of 10 regions (five developed and five developing) and 10 commodities, such as grains, consumer goods, and services. In any given year, the 10 regional submodels are tied together by linear restrictions on trade flows. The objective function is the "gross world product," defined as the sum of regional gross national products.

A development trajectory is generated as follows: starting with a base year, an optimal solution (over all regions) is determined. Stock variables resulting in that solution are incorporated into the formulation of the problem for the next year. This procedure is continued for as many years as desired. Since years are considered consecutively, the output from the model provides world economic development perspectives rather than optimal development paths. Runs of the model for 1970 to 1980 indicate that DYNAMICO can replicate the observed performance of the world economy during that period. Current work with the model is aimed at generating possible development scenarios for the coming decade.

H. Solgaard is working on applications of statistical methods in marketing and organizational decision making. One project involved assessing multi-attribute utility models associated with faculty tenure decisions. A tenure candidate was viewed as a multi-attributed stimulus evoking a response by administrative decision makers. Data from a sample of 18 hypothetical candidates ranked by 29 judges were used to assess the "fit" of utility models. It was found that several different models could provide predictions that compare extremely well with the actual judgments.

In a second project, Solgaard is investigating how consumers evaluate the usefulness of product attribute information from different sources. The problem of analyzing subjective evaluations by consumers is of great interest in market research. Solgaard has used two methods of estimating the relative contribution of each attribute to the total evaluation: conjoint analysis and the analytic hierarchy process. In order to collect data which can be used to compare estimation methods, Solgaard is conducting experiments with subjects making nonroutine purchases such as stereo receivers. According to Solgaard, results to date indicate that the analytic hierarchy process has advantages over the conjoint analysis method.

D. R. Barr

PHYSICS

ELECTROVISCOUS TORQUE TRANSMISSION

It is well known that if an electric field is applied across certain dielectric materials, an increase in apparent viscosity occurs. The phenomenon, called the "electroviscous effect" has been investigated for almost 100 years (W. Konig, *Annalen der Physik*, 25 [1885], p 618). Various explanations for the effect have since been proposed, ranging from the orientation of polar molecules to electrohydrodynamic convection. No complete understanding has yet been achieved, and the subject continues to stimulate much interdisciplinary activity (P.A. Arp, R.T. Foister, and S.G. Mason, *Journal of Colloidal and Interfacial Science*, Vol 12 [1980], p 4). From a mechanical point of view, the application of electro-sensitive fluids in power control dates back to work by W.M. Winslow (*Journal of Applied Physics*, Vol 20 [1949], pp 1137-1140), who described a novel form of clutch.

Researchers in the Department of Mechanical Engineering at the Univ. of Liverpool have redesigned Winslow's clutch so that dynamic loading tests can be conducted with a variety of fluids. The device consists basically of two independently rotating metal discs separated by a several millimeter gap that contains the fluid to be tested. When few-kilovolt-potential differences are applied across the plates, the

torque transmitted between the two plates increases linearly with voltage.

The breakthrough that elevated the research from an investigation of an interesting phenomenon to a clutch development program was the discovery of an electroviscous fluid with reproducible properties that did not degrade over several months. The ability to control reliably the shear forces that can be sustained in a electrified liquid has a number of clear commercial and military applications associated with torque transmission, controlled damping, and braking functions.

The research was described to the author by J.L. Sproston, the project leader, and J.C. Gibbings, the department chairman. The experimental apparatus was a clutch mechanism (Figure 1) consisting of two brass plates, the upper one (1) formed as a circular spigot, the lower one (2) as a circular recess containing the fluid. When superimposed, the spigot extended into the recess to provide axial and radial clearance. Each plate was attached to a flange (3), which in turn was bolted to an aluminum shaft. Both the input shaft (4) and the output shaft (5) were machined to fit bearings (6), which were fitted to the casing (7) to prevent either of the plates from coming into contact with the casing and to provide a low friction surface on which the plates could rotate. A large circular base plate (8) was attached to provide a stable configuration and machined so that when the clutch was loaded, the lower drive shaft could pass through it.

To provide drive to the clutch, the lower shaft was fitted with a 13-mm diameter pulley connected by a belt to a variable speed alternating current motor. The upper shaft was loaded by a string running from the shaft over a bench-mounted pulley and then vertically to a weight holder. To apply the input voltage, two leaf-spring contacts were bolted, with suitable insulation, to the casing so that one made contact with the upper surface of the upper plate and the other with the lower surface of the lower plate.

The working fluid consists of a base oil and a suspension of 100- μ m-diameter dielectric particles in an oil-to-particle ratio of 1:2 by volume. In this particle concentration, the material has the consistency of paste and does not run. Previous research concerned with the electroviscous phenomenon rather than mechanical applications used much lower concentrations of contaminant in the oil. Sproston and Gibbings believe that

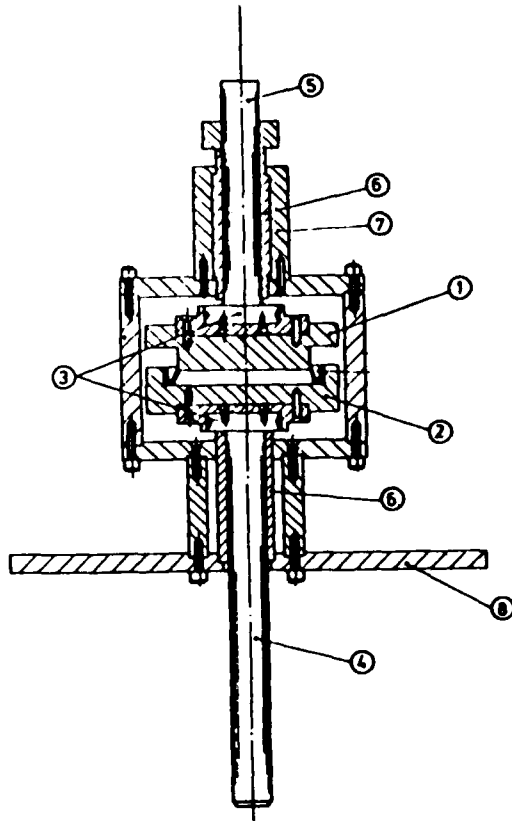


Figure 1. The clutch mechanism.

application of the electric field polarizes the particles. Dipole forces between particles cause the particles to align with the field in chains, thereby increasing the fluid viscosity. Suspensions with different diameter particles have not yet been investigated.

Plate gaps in the range of 1 to 4 mm with voltages of 1 to 4 kV have been investigated with the lower shaft driven at a constant speed of 50 to 60 rpm. The initial tests involved gradually increasing the potential difference across the plates until a point was reached at which the chosen load was just raised from the floor. The torque was then calculated as the product of the load and the radius of the upper shaft. Preliminary tests were also conducted in which the potential difference was applied not gradually, but at a rate of approximately 1 kV/s. Although not yet understood, a given viscosity is achieved at lower final voltage when the voltage rise is faster. Thus, the liquid appears to have a

memory function that does not degrade as long as the voltage is applied. At the highest applied fields, the suspension effectively becomes solid.

For patent protection, the researchers chose not to disclose the composition of the newly discovered stable fluid but provided data for several other oil-particle suspensions with similar electroviscous properties. The best performance reported was obtained with a silicone oil and starch combination. Results of tests with the material are in Figure 2. The figure shows a linear relation between applied voltage and sustained torque, and an increase in torque with starch concentration. Gaps of less than 2 mm were not tried because of the possibility of electrical breakdown. If breakdown occurs, the system must be taken apart and the fluid replaced. Operation near breakdown has not been attempted, so the maximum transmitted torque for a given clutch geometry has not been determined.

Figure 3 illustrates the variation of leakage current across the fluid with applied voltage. No large change in current is observed as a function of clutch speed and load. The electrical dissipation associated with operation of the clutch is in the microwatt regime.

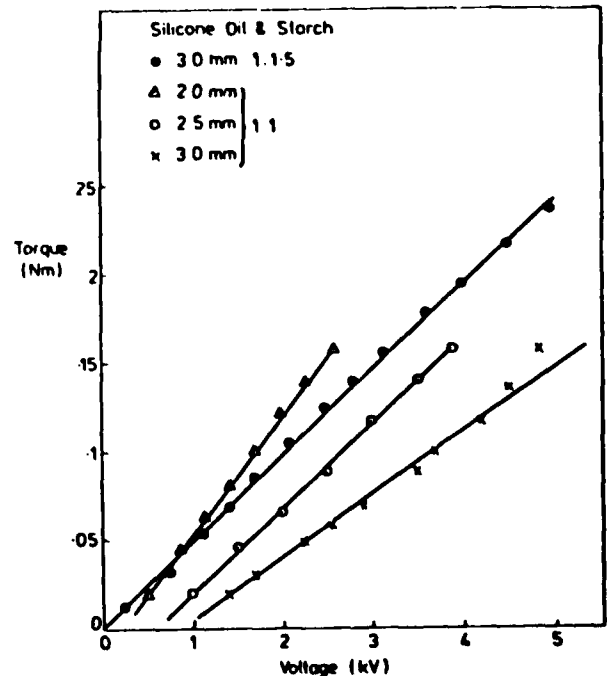


Figure 2. Torque versus voltage.

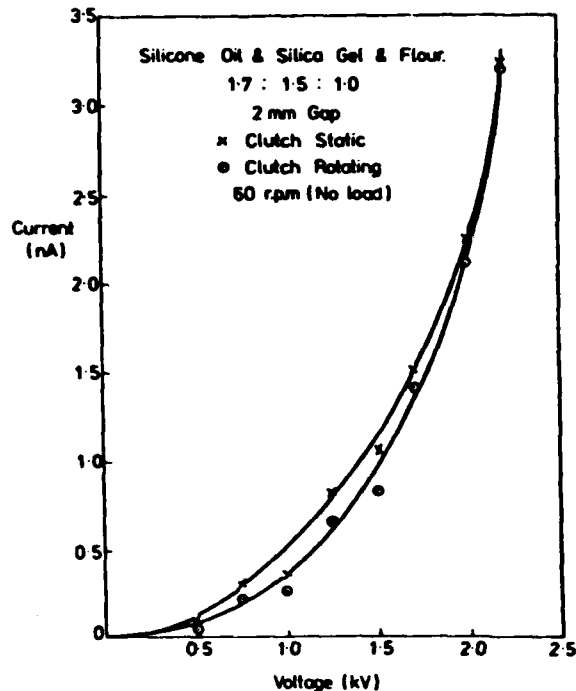


Figure 3. Interelectrode leakage current versus voltage.

The mechanism behaved well as a brake with the same fluids used in the clutch mode. When the output shaft's speed was slower than the drive shaft's, it was possible to produce controlled slippage by applying a voltage slightly less than that required for complete engagement of the plates.

A sealed unit is needed for normal horizontal shaft operation. A central disk can be encapsulated in a cylindrical cavity so that the electric field can be impressed on both sides of the disk across the cylinder end plates. This geometry doubles the torque transmission for a given plate diameter by providing viscous drag on both sides.

Research for the near future will be concentrated on improvements in geometry and investigations of heat dissipation and voltage time variations. The clutch geometry will be studied to reduce the electric stress at corners and thereby maximize the electric field which can be impressed without breakdown. The holding power at a given stress can also be increased by optimizing the clutch geometry. For example, a pair of nested cylinders rather than opposing disks can transmit greater torque because of the increased lever

arm to the rotation axis of points on the surface.

The effect of fluid temperature on torque transmission has yet to be investigated. It is therefore important to determine how well the plates can dissipate heat produced by viscous damping--especially in applications involving higher rotation velocities. It is planned to measure the temperature distribution within the operating clutch with thermocouples.

The curious effects of voltage time variations will be studied in a separate experiment with a vertical copper tube containing a coaxial steel rod. The fluid to be tested occupies the space between the two electrodes. The viscosity will be determined by measuring the head of liquid that can be sustained at a given voltage setting. The rate of voltage rise will be controlled by discharging a capacitor through a variable resistor with RC time constants in the 1- to 10-s range. There are not yet any firm plans to apply oscillating electric fields, although their use for speed control seems promising.

In summary, the Liverpool group has demonstrated a smooth variation of viscosity with electric field in a clutch geometry. The repeatability and long-term stability of the electroviscous fluid indicate a variety of torque transmission, variable damping, and braking applications. The response of the fluid to time-varying fields is not yet understood, and that phenomenon, along with temperature and high-rotation speed effects, must be investigated before the full potential of the system can be determined.

D. Mosher

LASER PROJECTION VIDEO

Anyone who has ever watched a commercial projection television system is immediately aware of its drawbacks. Since the image is the optical projection of a cathode ray tube (CRT) image, it has low brightness. Therefore, only screens of modest dimensions and with highly directional reflective properties can be used, and the room must be dimly lit.

Different lenses are used to focus the three primary colors, so convergence into a single image is difficult. (Typically, there is a blue halo on one side of an image, a red one on the other.) The low f-number Fresnel optics

needed to maximize brightness are difficult to focus, so resolution is usually less than that on the CRT.

All the above problems appear to have been solved by a radical approach researched and developed at Dwight Cavandish, Ltd., of Little Paxton, Cambridgeshire, UK. M. Shortle, chairman of the corporation, described the system to the author and discussed its areas of application. Three laser light lines in the primary colors are electronically modulated by the video signal and combined on a mirror system which sweeps the single beam across the projection screen in a manner similar to the electron beam sweep in a CRT.

The on-screen light power is much higher than can be achieved with conventional systems, so larger screens with wider dispersion can be used. The image is sharp at any distance because it is a scanned small-diameter beam rather than a focused image. Convergence problems are eliminated by combining the three colors within the instrument rather than projecting them separately. The intrinsic resolution is higher than available on color CRTs because it is set by the laser optics and modulating electronics rather than a dot matrix.

As presently configured, the prototype laser projection system is designed to operate in the standard 625-line PAL (English) and NTSC (American) television broadcast formats and can illuminate a theater-sized screen with broadcast or taped programming. Modifications to the scanning mechanism will allow the new world standard (1250 line) satellite broadcast format to be displayed. The current 15-MHz bandwidth provides a factor of three or four greater intrinsic resolution than a CRT, and the system can achieve a 50-MHz bandwidth. The system can illuminate screens with various aspect ratios of length to height so that, for example, a wraparound 120-degree horizontal field of view can be illuminated with a single projector.

In addition to the obvious commercial uses, the above qualities make the laser projection system valuable for a variety of technical applications. Computer-generated text and graphics can be projected with high resolution. The system offers large-area display of complex networks for simultaneous viewing by a large number of people, industrial and research facility system states, and other information previously displayed by CRT or electromechanical means. The projection size, resolution, brightness, and on-line computer control can provide improved realism in training simulators for ship and aircraft.

The company's first technical customer may well be the Cardiff Ship Simulator (CASSIM) at the Univ. of Wales Institute of Technology (see the article in ESN 37-1:1 [1983]). Three (and eventually five) conventional back projection units now provide a panoramic view in the simulator. CASSIM and UK Department of Industry personnel are investigating replacement of these units with two front projection laser systems mounted above the bridge.

The workhorse of the system is an Innova 90 argon discharge laser, which emits almost 10 W of light in a number of green and blue lines at the rated 14-kW electrical input. The laser light is angularly dispersed by a prism into its component lines. The dominant green line is then split and a portion is used to fluoresce a dye laser operating in the red at about 610 nm. Each of the three primary color beams is then modulated by the corresponding video signal. Modulation is accomplished by piezoelectrically driven ultrasonic waves in a crystal. (Details were not volunteered, but this technique has been widely researched.) The impressed bulk wave pattern diffracts the incident beam as it traverses the crystal with the time variation of the video drive. The modulation technique provides a 100 to 1 contrast ratio in the image. However, since the diffracted rather than the straight-through portion of the beam receives the modulation, most of the laser light is not used and is lost in a beam dump.

The three modulated beams are combined on a mirror that rotates at 39,000 rpm and provides the horizontal scan in the PAL format. The high resolution (1250 line) format will require faster mirror rotation in vacuum. The vertical scan is provided by a rocking mirror. Since the beam divergence is negligible, lens optics are used to diverge the exiting laser beam enough to fill the image plane without gaps. About 0.5 W of light arrives on the screen.

I saw the system in operation using a bar generator and PAL broadcast drive and projection onto a 7-ft by 10-ft screen. Shortle indicated that the system had not been adjusted since shipment to the company following a London demonstration, and that I was viewing half-power operation. He also stated that using the laser system to project standard transmissions was akin to playing an old 78 rpm recording on modern stereo equipment. Aberrations and noise in standard transmissions, unnoticed on a conventional monitor, are obvious with the laser projector. A

true demonstration of the system's capabilities requires that it be driven with the unmodulated RGB (for the three primary colors) system used for satellite transmission.

Even with the above disadvantages, the performance was impressive. The projected image was sharp and undistorted, with good color and true black and white. However, the room lights had to be dimmed so that the screen would be bright enough. The resolution was superior to that displayed on the nearby CRT monitor, resolving the finest (6.5-MHz) bars on a BBC test pattern. Because the projected laser light is coherent, one can see speckle patterns on the screen associated with interference effects. Although I was not disturbed by their presence, Mr. Shortle indicated that the speckle problem is being addressed and is close to solution.

The cost (£60,000 for a commercial unit, about \$100,000 for high-resolution specialized applications) and high power consumption put the system out of reach of the local pub owner. However, the unique capabilities of laser projection video make it ideal for a variety of research, industrial, and military applications involving the display of computer generated graphics.

D. Mosher

SPACE SCIENCE

ATMOSPHERIC PHYSICS IN BOLOGNA

Research in atmospheric physics is conducted at two principal sites in Italy: the Institute of Atmospheric Physics in Rome and Laboratorio FISBAT (formerly known as the Laboratory for Atmospheric Physics and Chemistry) in Bologna. Both facilities are research laboratories of Italy's National Research Council, known as the CNR (Consiglio Nazionale delle Ricerche). This article describes the atmospheric research program at Bologna.

The group at Laboratorio FISBAT-CNR consists of about 12 people and functions under the capable scientific leadership of G. Cevolani. Cevolani has this important role, though holding only a part-time appointment with nominal remuneration at the laboratory. The principal activities of the laboratory are to operate the meteor radar station near Bologna and to archive and analyze

the data obtained. The meteor radar approach is the basis of a unique method for studying properties of the upper atmosphere.

Several billion meteors of mass greater than 10^{-4} g and velocity in the range of 12 to 72 km/s enter the earth's atmosphere each day. Each meteor loses its energy through atmospheric collisions and produces an ionized trail that is approximately cylindrical with an average length of about 10 km. The basic measurement is of the reflected radar signal produced by the meteor trails. The atmospheric region monitored ranges from approximately 70 to 100 km altitude, over a horizontal area of about 2000 km². Above the upper limit of the altitude range (about 100 km), the atmosphere is insufficiently dense to cause ionization, and the incident meteors are invisible to the radar. Because of burn-out, no appreciable meteor flux remains below about 70 km. The information gained about the structure of the atmosphere derives from the theoretical description of the measured meteor signal.

The transmitting radar station, built in Bologna and located about 25-km away near Budria, has the following operating characteristics: frequency, 42.6 MHz; pulse duration, 10 μ s; pulse repetition rate, 140 Hz; peak power, 200 kW; and transmitting antenna gain, 17 dB. The transmitted beam has a conical width of 30 degrees and controlled phase shifted components. The receiving network consists of an array of phase-sensitive detectors, receivers, and orthogonally arranged antennas that form an interferometric system.

Interferometry and the echo delay time determine the location of the reflecting meteor trail. An elaborate and efficient real-time data processing system has been developed to schedule operations, recognize and select useful echoes, track echoes in time, and analyze the entire radar return signal continuously. The reduced data are stored on magnetic tapes. The Budria station now operates automatically, and the data reduction programs are developed and maintained by A. Dardi.

The measured physical quantities are the collected power, pulse shape, and time delay of the reflected signal. The power allows a determination of the height and radius of the meteor trails, and the time delay determines the ambipolar diffusion coefficient. From these variables the density and temperature of the neutral atmosphere are calculated as a function of altitude. The altitude of the meteor trails is

determined with a resolution of about ± 2 km.

Winds produce dramatic effects on meteor trails. Radar observations of the trails have been analyzed to infer characteristics of the thermospheric wind system in the altitude range of about 80 to 100 km. Spectral analysis of the Budrio (44°N, 12°E) data has determined mid-latitude thermospheric winds, wind structure, and fluctuations. Average wind values, long-period variations (> 1 month), daily variations known as atmospheric tides (≤ 1 day), and rapid oscillations (down to fractions of an hour) have been systematically determined. Some indicative average values are a wind speed of 28 m/s, a regular semidiurnal tide of 21 m/s, an irregular diurnal tide of 10 m/s, and many variations in period from 19 to 32 hours. Some measurements suggest the presence of large vertical flows, implying a complex three-dimensional structure for the thermospheric wind system. Tidal waves (periods of 8, 12, 24 hours), longer period waves, and seasonal variations have been systematically determined, as have gravity waves (periods of 2 to 10 hours) and energy loss rates. Gravity waves have both a horizontal and vertical structure and play an important role in the transport and redistribution of energy and momentum in the atmosphere.

Simultaneous observations of selected meteor showers from Budrio, Ondrejov (Czechoslovakia), and Gissar (USSR) have produced interesting results. Coordinated observations were conducted to reduce the effects of factors such as instrumental error and local atmospheric anomalies. With the impending passage of Comet Halley in 1986, the Orionids and Eta Aquarids meteor showers were observed. The showers occur at the points in the earth's orbit most closely associated with Halley's orbit. Structural features of the Orionid shower of 8 October 1978 were determined, and the association of the shower with Halley was confirmed.

Recent emphasis has been in collaborative efforts using two or more meteor wind observing stations that are widely separated compared to indicative atmospheric wavelengths. Such coordinated observations are especially useful for discerning spatial and temporal wind variations, and for testing the validity of empirical wind models. The principal collaboration has been with S.P. Kingsley and H.G. Muller (Sheffield Univ., UK), who operate an automatic station similar to that of the

Bologna group. The two groups use common methods of data analysis that are appropriate for the observed bandwidth frequencies, which may not be stable. Tidal modes expected theoretically have been identified, but greater vertical resolution is needed to distinguish between the most energetic modes in the rather narrow atmospheric layer where meteor trails occur. Mean observed tidal patterns agree well between stations, but significant variations in phase and amplitude are typical in real-time comparisons. The variations may be due to interactions between modes generated at lower atmospheric levels with solar tides. In a collaboration involving J.L. Fellous (Issy les Moulineaux, France) and five stations, the conclusions were substantiated and extended. (See the paper by Fellous, Cevolani, Kingsley, and Muller, "Atmospheric Dynamics Observed During the Energy Budget Campaign," *Journal of Atmospheric Physics* [In press, 1982 or 1983].)

Radar meteor studies have several advantages. They are ground based and inexpensive, operations are systematic and long term, and a continuous data base is generated; in addition, the region of the thermosphere monitored is difficult to access by other means. Meteor studies are useful inputs and are actively solicited to contribute to international campaigns such as the Middle Atmosphere Program (MAP) and the Stratospheric Warming Mesospheric Program (SWAMP). The science planned for MAP requires global inputs, involving latitudinal and longitudinal structures, to which radar meteor studies can contribute significantly.

In recent years, much effort has gone into understanding the electrical coupling between the earth's magnetosphere and ionosphere. Magnetic field aligned currents enter and leave the ionosphere at high latitudes in the auroral zone. These electrical currents spread globally throughout the ionosphere and generate winds. A major question is the degree of coupling and energy transfer between high and low latitudes by the process. Radar meteor studies may be a useful and independent way to address the question for middle latitudes. The continuous meteor trail data base could be used to study geomagnetically disturbed periods selectively when the electrical coupling would be largest.

The measurements at Bologna and the related scientific publications are of high quality and widely recognized. Cevolani, in particular, has sustained an active publication record and

promoted international collaborations. It is impressive to note the increasing sophistication over the past decade of the meteor radar data analysis methods now used routinely to identify atmospheric structure.

R.L. Carovillano

STATISTICS

MEGALITHIC STATISTICS

The British Isles and parts of northwest Europe contain many prehistoric ruins characterized by large stones in various geometric arrangements, earth mounds, and burial chambers. The diverse archaeological sites are called "megolithic," and there is evidence that the monuments were built from 4,000 B.C. to 1,000 B.C.; their purpose is not entirely clear.

Stonehenge is perhaps the best known of the sites--in part because of the controversial but popular book Stonehenge Decoded, by G. Hawkins and J.B. White. The book is concerned with the orientation of stones at the site, and especially with alignments corresponding to points where the builders of Stonehenge could have observed various astronomical events. Included are not only points on the horizon where the sun and moon rise and set at times such as the sun's summer solstice, but also various points in the apparent motions of planets and bright stars.

The accuracy of the alignments is still open to debate. In addition, there has been considerable interest in how the stone configurations were built and in whether a standard length measure (the "megolithic yard") might have been used in constructing many of the megolithic sites. More specialized studies concern the number systems used by the builders and the use of alignments to date the sites. The latter work attempts to exploit drift of certain "significant" points on the horizon over long periods of time. Assuming a given line pointed at a specific significant point when the site was built, researchers attempt to determine the epoch during which that significant point actually aligned with the given line. A good introduction to the subject is given in D.C. Heggie, Megalithic Science (London: Thames and Hudson, 1981).

With a number of stones at a given site, there can be a large combination

of potential alignment lines. There are also a fairly large number of potential points on the horizon that are of astronomical significance. Thus, the statistical question is whether the number of alignment lines between stones with "significant" points on the horizon is larger than could be attributed to chance alone. That is, if such a site were rotated in the plane by a random angle, how many "alignments" might result?

It is clear that there is considerable room for controversy about issues such as physical problems of defining lines between stones (which parts of the stones are the actual sight points), the accuracy with which the builders might have constructed such sighting stones, and the selection of "significant" points on the horizon. Such issues have been subjected to increasingly careful scrutiny in recent years. Major contributions have been made by A. Thom, who might have been the first scientist to use a statistical approach with data from many megolithic sites. Thom also recognized the problem of chance alignments and the tendency of investigators to select "positive" evidence. Several statisticians--including S. Broadbent and M.G. Kendall in the 1950s, and more recently D.G. Kendall and P.R. Freeman--have contributed methods of assessing the significance of alignments, geometric "fits," and megolithic length units associated with the sites.

Freeman is Professor of Statistics and chairman of the statistics group in the Department of Mathematics at Leicester Univ., UK. During a recent visit, Freeman described some of his research efforts aimed at developing statistical methods appropriate for megolithic applications. One technique was Bayesian Analysis of the megolithic yard. From a large number of megolithic sites, Thom collected survey data, which he made available to the scientific community. As a result of analyses of his data, Thom concluded that the builders of many sites had a unit of length--that he has called the megolithic yard--equal to 2.72 ft. The length varied from site to site by no more than a few thousandths of a foot.

Freeman's analysis uses Thom's data from circles and rings of standing stones and from long parallel rows of stones. Given a set of observations of lengths (ring diameters, for example), y_1, y_2, \dots, y_n , that arise as integer multiples of some basic standard length δ , a model for the observations is that each y_i is equal to some multiple m_i times δ plus a random error term ϵ_i . Practical

considerations for the megalithic sites suggest that δ must be in the range of 2 to 11 ft.

Freeman assumes the E_i values are normally distributed with mean zero and unknown variance σ^2 . He thus considers the conditional likelihoods of the y_i values--given the m_i values, δ and σ --to be of multivariate normal form. He assumes a uniform prior for the m_i values and calculates the posterior for δ in which σ is a parameter. By examining plots of log posterior as a function of δ for various fixed values of σ , Freeman has concluded that none of the sites from England and Wales provides evidence of the existence of a megalithic yard, δ . He observes that data from Scottish sites do indeed provide strong peaks in the plots corresponding to $\delta = 5.45$ ft, as well as possibilities at 4.00 ft and 7.50 ft. It should be noted that a standard of length of 5.45 ft for diameters would imply a radius standard very close to that claimed for Thom's megalithic yard.

Freeman has also been interested in assessing the significance of alignments at the megalithic sites. He comments that "the apparently simple objective of deciding whether a set of apparent astronomical alignments can be ascribed to chance coincidence or whether there is something in them, turns out to be not at all simple." To assess a given alignment, one must consider the latitude λ of the site, the azimuth A of the alignment, and the angle of elevation h of the horizon in the direction of the alignment, corrected for atmospheric refraction. From these, the declination δ of the alignment can be calculated. It can be called a "hit" if close enough to the declination of one of the astronomically significant points on the horizon.

Freeman has conducted a rather extensive assessment of what might be the astronomically significant points; considering only the sun and moon, he suggests a set of about 100 such points. Instead of defining the level of closeness of an alignment to one of the points, he plots values of the test statistics he uses as functions of the closeness definition, α . If r_i is defined to be 1 if alignment i is a hit (and r_i is zero otherwise), the logarithm of a maximized likelihood ratio can be written as the sum (over i) of r_i times $\log p_i$, where p_i is the probability of a hit as a function of α , under the hypothesis that

alignments are random (uniformly distributed).

Arguing that the above statistic is asymptotically normal, Freeman suggests its standardized version as a test statistic. With data from a given site, he plots values of the test statistic as a function of α . If the plot nowhere falls below -2 or so, he concludes that there is no evidence for the astronomical hypothesis. If the plot falls below -3 or so for at least one value of α , he concludes the astronomical hypothesis should be "seriously considered"--i.e., that the builders of the site may well have purposely constructed alignments coinciding with significant astronomical points on the horizon.

D.R. Barr

NEWS & NOTES

WHY MRS. THATCHER IS FREQUENTLY INTERRUPTED

If a conversation is to proceed smoothly, the participants have to take turns speaking. Studies of conversation have shown that there are signals which speakers give to inform listeners that they are willing to hand over the conversational turn.

Some of the signals are part of the text (for example, completion of syntactic segments), some are nonverbal (such as completion of a gesture), but most are carried by the pitch, timing, and intensity pattern of the speech. For example, both pitch and loudness tend to drop particularly low at the end of a speaker's turn. When one speaker interrupts another, the two can be said to be disputing who has the turn. Interruptions can occur because one participant tries to dominate or disrupt the conversation, or because there are mistakes in the way subtle turn-yielding signals are transmitted and received.

In a recent article in *Nature*, G.W. Beattie of the Univ. of Sheffield, and A. Cutler and M. Pearson from the Univ. of Sussex, Brighton, analyzed the British Prime Minister's voice to see why Mrs. Thatcher is interrupted so often. They demonstrated that in a TV interview, many interruptions occur when her turn appears to have finished.

Forty extracts containing at least one sentence were presented to subjects who had to judge whether Mrs. Thatcher's

turn was complete or not. The extracts were presented on video to 79 subjects, on isolated audio to 29 subjects, on isolated vision to 14 subjects, and in transcript to 20 subjects. For each of the 40 extracts in each of the four modes of presentation, the percentages of completion judgments were calculated.

The results supported the hypothesis that utterances preceding an interruption by the interviewer displayed turn-yielding cues at inappropriate points. Subsequent voice analysis indicated that Mrs. Thatcher gave conflicting cues associated on one hand with the rate of fall of frequency, and on the other with final frequency. Although the speaker was giving cues about the end of her turn, the cues she considered paramount might have been different from those the interviewer considered paramount.

Thus, the researchers argue that Mrs. Thatcher is interrupted because of her inappropriate turn yielding cues and not because interviewers want to dominate or disrupt conversation.

D. Mosher

LONDON GETS COMPUTER CONTROLLED SAFE DEPOSIT VAULTS

Using a system designed and built by Rosengrens of Gothenburg, Sweden, four new London safe deposit centers are scheduled to open this month. They feature spacious temperature and humidity controlled lockers of varying sizes--from small drawers to large safes capable of accommodating art treasures.

Each depositor is issued a magnetically encoded card and a personal identification number which is used with the card. Once identified, the customer passes through the massive vault door and through several electronically controlled gates leading to his locker. If lockers other than his own are touched, a warning siren sounds. The average cost of a locker is £200 (\$320) per year, including insurance. The vaults are open 24 hours a day every day and have guards on duty at all times. Each center has 5000 lockers.

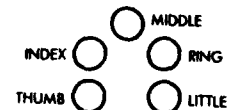
M.N. Yoder

THE MICROWRITER: A ONE-HAND KEYBOARD DEVICE

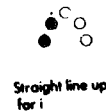
There are several bottlenecks in the long process of converting thoughts and observations into print. The most critical one is the writer's problem, the organization of ideas and materials into coherent discourse. But even when the writer is fairly clear about what should be said, it takes a long time to write by hand, or dictate into a voice recorder, and then have a secretary type the material. The Microwriter, now produced in London, is an interesting alternative to the usual writer's aids.

Microwriter is portable, about the size of a small tape recorder. Its central input device is a five-finger keyboard which can record a considerable range of alphanumerics and technical symbols. The original copy goes into a 1,600-word memory, where it can be retrieved immediately for display and editing. Most important, the character memory can be "dumped" automatically into a word-processor or electric typewriter. During the initial data entry, requirements for pagination, identification, and line return are easily incorporated. Portability means that a person on a train or airplane can "write" directly into the keyboard. Then back at the office, the rough copy is printed out ready for editing in a few minutes, with no secretarial intervention until the initial editing is finished.

Ergonomics professionals should be intrigued with the way letters are encoded into the five-key system. The user has to think of the five keys as forming a geometric pattern:



When certain keys are pressed, letters are printed. To make an "i," for example, you press the two left-most keys, remembering "straight up for i."



To make an "r," you add a bar at the top of the "i":



But for an "h," you make a horizontal bar across the bottom of the keyboard:



Horizontal of the H

"E," the most common letter, requires the "easiest" finger, the index:



Most common finger (Easiest) for most common

The input keying system is thus an unusual mixture of graphic stereotypes and "popularity" keying. It probably deserves intensive human-factors evaluation because, in addition to the usual business applications, there are many control situations in which a one-hand, but easily learnable, keyboard should be of considerable value.

N.A. Bond, Jr.

system that requires only one good foot, or even one finger, for road operation. The stick can be located anywhere in the car.

As now fitted in small cars like the Ford Escort or the British Leyland Mini, the joystick has three potentiometers and thus three electronic channels of information. Two channels are used to drive the servos that turn the wheel. The system's "hiccups" and failures have been corrected, and it seems to be reliable enough for practical road use. One driver, steering only with her left foot, was able to pass the stringent UK driving test; and over an 18-month period the system has not failed under her use. Reportedly, the Thalidomide Trust has ordered some experimental cars to be fitted with the system; few thalidomide victims can drive cars with standard steering. As shown in Figure 1, the joystick control can be switched off easily, and the car then can be steered normally.

N.A. Bond, Jr.

A JOYSTICK CONTROL SYSTEM FOR AUTOMOBILES

The adaptation of cars for handicapped people is a specialized industry, and various systems have been used for some years. Perhaps the most popular ones provide a "hands-only" capability. The Univ. of Reading (UK) and Malden Care Electronics (Raynes Park, London) have been evaluating a joystick steering

MICROCOMPUTER AIDS TO SHIP TECHNOLOGY

A 1-day seminar on Microcomputer Aids to Ship Technology (MAST) was held in Chichester, UK, on 24 November 1982. The seminar, sponsored by Duncan Marine and Commercial Craft, Ltd., included talks about and demonstrations of low cost computer systems for naval architecture and computer aided drafting.

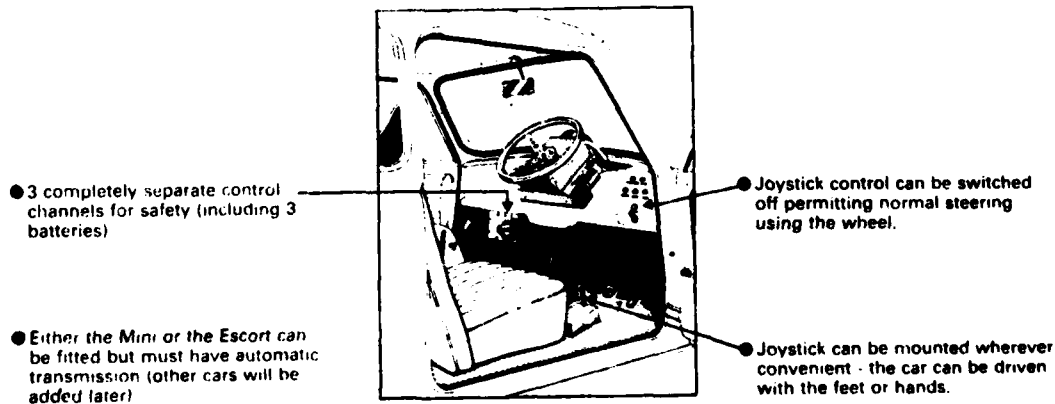


Figure 1. Joystick control system.

The MAST set of computer programs for vessel design, evaluation, and development, and for ship-born loading calculations were demonstrated and discussed. The systems operate on low cost microcomputers and provide extensive facilities to support computer aided drafting for hull design drawings.

An extensive range of calculations required to assess the design and safety aspects of a vessel are included: calculations of hydrostatics, floodable length, cross curves, weights and centers, loading constraints, trim and stability, and compartment capacities. Transverse hull section drawings are also provided. The results of all the functions also can be plotted automatically. The user can select trim and draft ranges required, as well as the intervals at which calculations are to be performed.

A digitizer is used for automatic collection and input of rectangular coordinate data for volumetric definition and weights and centers calculations. Results can be shown on a visual display unit and printed or plotted on an integral thermal printer of the system or on a separate plotter-printer.

All input data and results are stored on cassette or disc file for future access without the need for recalculation.

J.F. Blackburn

CHEMICAL PARTITIONING IN CONDENSED PHASES, ATOM BY ATOM, AT OXFORD

G.D.W. Smith, at the Department of Metallurgy and Science of Materials, Univ. of Oxford, is actively involved in atom probe-field ion microscope (FIM) studies of atomic microstructures in single and polyphase systems. The modern FIM, including the imaging atom probe with time-of-flight mass spectroscopy, gives a unique combination of chemical and structural information on the ultramicro scale.

Figure 1 shows an edge-on FIM view of a single cementite lamella enclosed on either side by a ferrite lamella--all contained within a pearlitic eutectoid steel alloy (see P.R. Williams, M.K. Miller, and G.D.W. Smith, "The Partitioning of Alloy Elements During the Pearlite Transformation: An Atom Probe Study," in International Conference on Solid State Phase Transformations, Pittsburgh, 1981, eds. H.I. Aaronson and C.M. Wayman [In press]). The cementite



Figure 1. FIM image with neon at 12.5 kV of chromium pearlitic steel alloy.

lamella is the dark band, about 10-nm thick. This relatively fine microstructure was transformed from austenite below the thermodynamic no-partitioning temperature.

Figure 2 shows an elemental analysis by atom counting during desorption of another tip structure. Conditions were similar to those in Figure 1, but for Figure 2 the atomic composition was measured orthogonally to the cementite-ferrite interface. So beginning on the abscissa scale of counting atoms, they are sequentially removed in depth from the cementite phase until it is gone, and then atoms are progressively removed from the ferrite phase. Each point in the figure for the content of carbon, iron, chromium, manganese, and silicon atoms represents the number taken over 400 atoms in the counting interval.

The 5-nm marker shows the physical depth that has been traversed during the sequential removal of atoms. In this case, the pearlite was transformed for 2 minutes at the nose of the ttt curve, 597°C, where information was desired on the extent of the redistribution of alloying elements during the transformation. The results show that significant redistribution of all of the alloying elements has occurred. A full analysis has shown that a short-circuit diffusion mechanism operates for

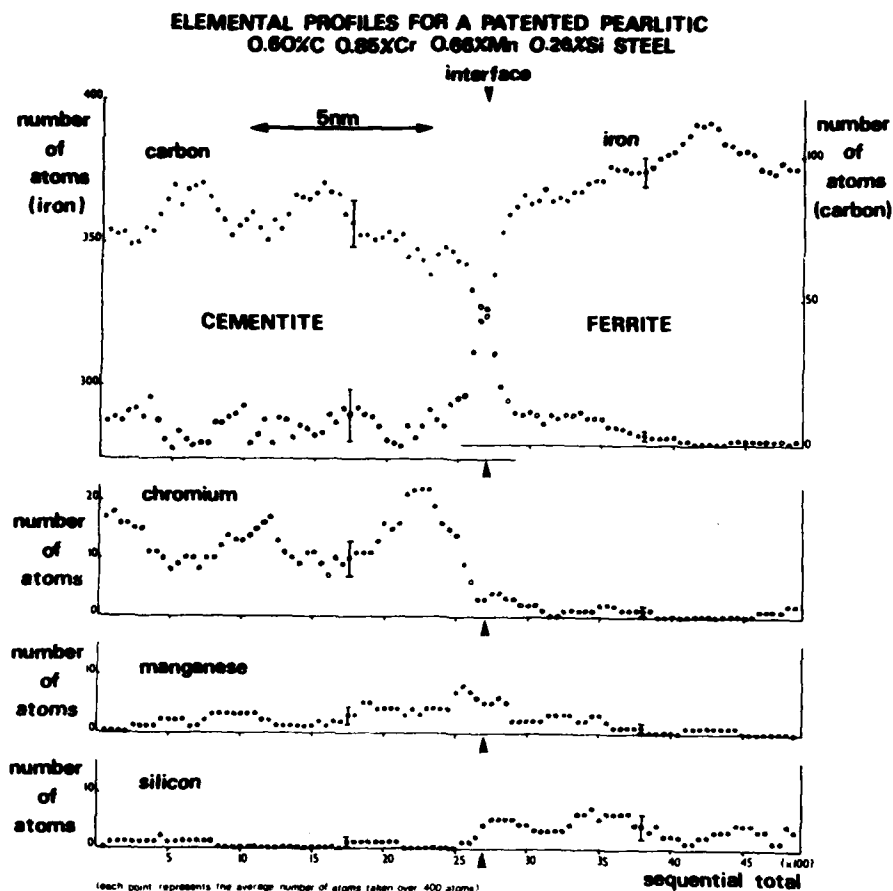


Figure 2. Atomic composition measured orthogonally to the cementite-ferrite interface after isothermal transformation for 2 minutes at 597°C.

chromium at the pearlite interfaces. Further analysis of the more sluggish diffusion of manganese is being done.

Smith spent a short period at the US Steel Corporation Research Laboratory with S.S. Brenner, who has done pioneering research on the modern development of the FIM. In 1980, Smith spent a sabbatical leave period at MIT with J.B. Vander Sande and A.J. Garratt-Reed, and was there for several weeks in 1981 to study the enrichment of chromium in the pearlite interfaces. Miller is now at Carnegie-Mellon Univ. as a research fellow and is working in collaboration with Brenner. W.A. Soffa at the Univ. of Pittsburgh is also very much involved in research on this topic. P. Haasen and colleagues at Göttingen are doing important work on the subject. (See ESN 36-10:272 [1982] and the article "Metal

Physics at Göttingen," elsewhere in this issue.)

At Oxford, the FIM is being applied to other problems as well—for example, the characterization of silicon surfaces for electrical properties information (to be reported in *Surface Science* by C.R.M. Grovenor and Smith) and a study of the oxidation of rhodium-platinum alloys for catalysis information (reported in *Platinum Metals Review*, 27, 83, pp 19-25, by A.R. McCabe and Smith). Why not a study of carbon locking at an individual dislocation in α -iron? Smith and colleagues have just done it, and they will soon report the new information obtained.

R.W. Armstrong

THE NORTH SEA CENTER AND R/V DANA

Founded in 1979, the North Sea Center is a nonprofit organization for fishery and marine research. It is in Hirkhals, Denmark, where construction of the center is expected to be completed by December 1983. The cost of building the new facilities is more than \$15 million and is being financed by various Danish and European grants and loans.

The Danish Institute of Fisheries Technology, part of the North Sea Center, has several facilities:

- Library and documentation center
- Flume tank for scale model experiments with fishing gear
- Fishing simulator (detection and catch)
- Laboratories for making tests under varying environmental conditions, including arctic and tropical.

The institute is affiliated with the Danish Academy of Technical Sciences.

Several other organizations are part of the North Sea Center. The facilities of the Danish Institute for Fisheries and Marine Research include biological laboratories and aquaria. The North Sea Museum has a public aquarium and exhibition center.

The North Sea Center has offices, classrooms, and workshops for advanced training in fisheries. The Aalborg University Center is housed in the educational facilities. Accommodations for guests and students are also available. The center's Division of Industry has several buildings with offices and showrooms that private enterprises can use for research, demonstration, and advertisement purposes.

Connected to the new center is the Research Vessel (R/V) DANA, a stern trawler built in 1981. Owned by the Danish Ministry of Fisheries, DANA is fitted with advanced equipment and laboratories for fishery investigations and for physical, chemical, and biological research. The vessel accommodates 12 scientists and 26 officers and crew.

R/V DANA (overall length, 78.43 m; 2484 tons) has two diesel main engines; an automatic maneuvering system; bow and stern thrusters; advanced navigation and communications equipment (including satellite systems); six main physical, chemical, and biological laboratories (including wet and dry fish laboratories); an acoustic detector room; a data processing room; two aquarium rooms; a trawler deck with two main winches; a hydrographic winch area; diving support

equipment; and workshops and additional facilities.

R.W. Booker

RUSSIAN SPACE PROGRAM NEWS

The USSR launches more satellites than all other nations combined. In contrast, the Russians have made relatively modest contributions to the space science literature, and their prominence at international meetings is similarly comparatively modest.

The Russian approach can be described as constrained with regard to releasing information on their space program. The British have a remarkable record of scooping them in announcing Russian activities in space. Most Russian announcements are made after the fact through official news releases.

The Daily SNAP (Soviet News Abstracts Publication), published by the US Foreign Technology Division, monitors and distributes Russian news releases. The original Russian reports on space activities are numerous, though often sketchy and limited in information. During the 5-week period beginning 1 December 1982, SNAP reported on the following Russian space activities.

Cosmonauts Berezovoy and Lebedev completed a record 211 days in space aboard the Russian space station Salyut-7. Before their return to earth, they were in apparent good health and feeling well. While in space the cosmonauts were serviced by a small cargo ship called Progress-16 and were provided with fresh vegetables--a space first. Progress-16 also delivered the Czechoslovak instrument EFO to measure the dust content and density of the atmosphere, and the Bulgarian imaging system Duga that stores data and images on tape in the space station. Cosmonaut departure preparations included loading and fueling the landing module Soyuz T-7 and closing up Salyut-7.

Despite the length of the flight, the safe landing window for Soyuz T-7 may have been quite restrictive. The cosmonauts landed in a blizzard that reportedly was not predicted by weather forecasters. The cosmonauts managed to disengage the parachute from the landing capsule, which nevertheless was shifted about by the high winds. The blizzard hindered the recovery mission and prevented normal press coverage of the landing. Two helicopters landed with difficulty but the third, containing the

medical unit, had to retreat when the weather worsened. After a difficult night, the rescue was fully under control. Within a few days the medical condition of the cosmonauts was reportedly very good as they readjusted to terrestrial conditions.

Upon landing, Berezovoy and Lebedev were described as thinner, with reduced muscle volume and density. The cosmonauts experienced discomfort in sitting for some days because of the diminished condition of the required muscles.

The Conference on Studies of Earth from Space was held in late 1982 at Baku, USSR. This was the first interdisciplinary meeting of its kind to study the biosphere and climate from space. The major problem is learning how to interpret accurately data and observations from space. Careful comparisons need to be made between earth objects with known characteristics and space measurements of the same objects. The Russians have expressed optimism for accomplishing major developments in climatology and oceanology through use of satellite observations over the next 10 to 15 years. A global three-dimensional picture of the oceans can be developed through use of subsurface acoustical observations in conjunction with electromagnetic measurements from space.

A dispatcher's call in Vladivostok was received by a taxi driver in Moscow some 4000 miles away. This is an unusual example of how ionospheric disturbances can affect communications. Because of an enhancement in the local ionization density in the ionospheric E-layer, the dispatcher's signal was reflected and received at an unusual distance. The Russians are considering active experiments such as ionospheric heating to create controlled modifications in communications.

An example of an announcement of a satellite launch is the Pravda report on Cosmos-1423. The satellite had been launched 2 days earlier with the following orbital parameters: period 94.3 minutes, apogee 575 km, perigee 401 km, orbital inclination 68.2 degrees. The purpose was to conduct space research; instruments on board were functioning normally. A more prompt and informative announcement was given for the meteorological satellite Meteor-2. In addition to orbital data, the operations of the satellite were described. Visible and infrared imaging were performed in both real-time and storage modes. Continuous monitoring at radio frequencies was also provided. Wide-

spread distribution of the data to several USSR institutions was planned.

R.L. Carovillano

PUBLICATION AWARD PRESENTED

Dr. David Mosher, currently serving as Liaison Scientist for Physics at ONRL, has been presented a Research Publication Award for 1982 by the Plasma Physics Division of the Naval Research Laboratory (NRL). Each research division selects one or two papers each year for honors based on the excellence of the research and its impact on the scientific community.

The award was granted to Dr. Mosher and his NRL associates F.C. Young and S.J. Stephanakis for "Measurements of Enhanced Stopping of 1-MeV Deuterons in Target-Ablation Plasmas," published in the 23 August 1982 issue of Physical Review Letters. The NRL staff members, along with S.A. Goldstein (Jaycor, Inc., Alexandria, VA) and T.A. Mehlhorn (Sandia National Laboratory, Albuquerque, NM), demonstrated that fast ions lose energy in a plasma at a higher rate than in cold, solid matter. The reduced ion range in plasmas improves the chances of success for controlled fusion in deuterium and tritium bearing pellets driven by intense ion beams. If successful, the process could produce electricity in a fusion reactor using as fuel heavy isotopes of hydrogen extracted from seawater.

F.A. Richards

EUROPEAN VISITORS TO THE US SUPPORTED BY ONR LONDON

| <u>Visitor</u> | <u>Affiliation</u> | <u>Organization to be Visited</u> |
|-------------------|---|---|
| Dr. J.D. Burton | Department of Oceanography Univ. of Southampton, UK | NPG School, Monterey, CA NOSC, San Diego, CA (7-11 February 1983) Scripps Institution of Oceanography, Univ. of California, MIT (7-14 February 1983) |
| Prof. H.C.A. Dale | Ergonomics Research Group Univ. of Hull 26 Newland Park Hull HU5 2DW | Navy Personnel Research & Development Center, San Diego, CA (27-29 June 1983) Aviation Psychology Lab Ohio State Univ. (4-6 July 1983) Wright-Patterson AFB (4-6 July 1983) |
| Dr. J.C. Duinker | Netherlands Institute of Sea Research, Den Berg, Texel, The Netherlands | Skidaway Institute of Oceanography Savannah, GA (5-8 February 1983) Gordon Research Conference on Chemical Oceanography Ventura, CA (30 January-4 February 1983) |
| Dr. S. Forsen | Physical Chemistry Div. Chemical Center Univ. of Lund Sweden | ONR Biosciences Lab San Diego, CA (13-15 February 1983) George Washington Univ. Medical School, Wash. DC (21 February 1983) ONR (21 February 1983) |
| Dr. R. Huber | Hochschule der Bundeswehr München Neubiberg, FRG | CNA, Alexandria, VA NPG School, Monterey, CA (June 1983) |
| Dr. K. Kremling | Institut für Meereskunde Kiel, FRG | Skidaway Institute of Oceanography Savannah, GA (7-8 February 1983) Gordon Research Conference on Chemical Oceanography Ventura, CA (31 January-5 February 1983) |

| <u>Visitor</u> | <u>Affiliation</u> | <u>Organization to be visited</u> |
|----------------------------|---|--|
| Prof. M.S. Longuet-Higgins | Department of Applied Mathematics and Theoretical Physics Univ. of Cambridge Silver Street Cambridge CB3 9EW | NORDA (17-18 February 1983) Univ. of Florida Gainesville, FL. (January, February 1983) |
| Dr. R.F.C. Mantoura | Institute for Marine Environmental Research Plymouth, UK | NOSC, San Diego, CA (6-7 February 1983) Univ. of Rhode Island (11 February 1983) Woods Hole Oceanographic Institution (9/10 February 1983) |
| Dr. J. Swithenbank | Department of Chemical Engineering Univ. of Sheffield Mappin Street Sheffield S1 3JD | NWC China Lake, CA (8 March 1983) Edwards AFB, CA (7 March 1983) Sandia Labs, CA (9 March 1983) |
| Dr. H.J. Zimmerman | 5100 Aachen-Kornelimünster Korneliusstr. 5 Aachen, FRG | NPG School, Monterey, CA Stanford Univ. (Both January 1983) |

ONR COSPONSORED CONFERENCES

ONR London can nominate two registration-free participants in the conferences it supports. Readers who are interested in such participation should contact the Chief Scientist, ONR London, as soon as possible.

7th International Conference on Infrared and Millimeter Waves, Univ. of St. Jerome, Marseille, France, 14-18 February 1983.

OHOL Biological Conference on Mechanisms of Viral Pathogenesis (From Gene to Pathogen), Zichron Ya'acov, Israel, 20-23 March 1983.

First UK Solar Maximum Mission (SMM) Workshop, Oxford, UK, 9-12 April 1983.

International Conference on Insulating Films on Semiconductors, INFOS 83, Eindhoven, The Netherlands, 11-13 April 1983.

Conference on Magnetic Resonance Spectroscopy of Liquid Crystals and Biological Membranes, Leeds, UK, 18-20 April 1983.

European Specialist Workshop on Active Microwave Semiconductor Devices, Maidenhead, UK, 4-6 May 1983.

International Symposium on Phase Relationships and Properties in Multicomponent Polymer Systems, Capri, Italy, 30 May - 3 June 1983.

NATO ASI on Physics of Submicron Semiconductor Devices, Pisa, Italy, 10-23 July 1983.

8th European Symposium on Fluorine Chemistry (ESFC-8), Jerusalem, Israel, 21-26 August 1983.

International Conference on Electronic Properties of Two-Dimensional Systems, Oxford, UK, 5-9 September 1983.

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